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SPECIAL STUDY S-53-3

ARTIFICIAL FLOODING POTENTIALITIES

VENETIAN-FRIULI PLAINS OF NORTHEAST ITALY

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PREPARED BY
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WASHINGTON DISTRICT, CORPS OF ENGINEERS
WASHINGTON, D. C.
JUNE 1953

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ABSTRACT

This report presents the artificial flooding potentialities of the VENETIAN-FRIULI PLAINS. The effectiveness of artificial inundation is largely dependent upon the hydrologic conditions at the time of the operation. The volume of water stored and available in the river basin, the river stage and the rate of flow in the stream are important elements to be considered. The rivers in this area have a wide range between high and low flows. The magnitude of the area, the numerous existing hydraulic works, and the time allotted for the study limited detailed analyses to those structures and sites contributing to the maximum military effect.

The erection of temporary dams at bridge openings or at other restricted sections along the various streams, located between the ISONZO and ADIGE Rivers, would create still-water barriers. Formation of a continuous water obstacle by this means is practical only along the ADIGE River. Due to the nature of the terrain, still-water barriers on the other streams would be of short length along the stream and would spread out transversely over the adjacent land.

Sudden opening of gated outlets of the large power reservoirs in the region, such as the LUMIEI, PIEVE DI CADORE, S. GIUSTINA and S. VALENTINO DAMS, would create detrimental flow variations in the rivers downstream from the dams. This type of operation would not produce excessive velocities or increases in river widths in the VENETIAN-FRIULI PLAINS; however, appreciable changes in river depths could be attained along the TAGLIAMENTO, PIAVE, ADIGE and other rivers. A minimum increase of 0.5 meter and a maximum increase of 2.0 meters in river stages at various sites in the plains could be obtained with river widths of 0.1 to 1.5 kilometers and mean surface velocities varying from 0.7 to 1.5 meters per second.

Breaching of dams located in the ALPS mountains would create major flood waves of appreciable magnitude but of short duration. Major flood waves would produce increases in stages of 1.5 to 5.5 meters above normal water conditions, lasting from 0.5 to 1.5 hours above the river banks in the plains region. Maximum effects could be obtained by breaching those dams having large reservoir storage capacity and by locating the breach near the bottom of dams similar to the LUMIEI and S. GIUSTINA Dams. The best opportunities for creating major flood waves exist on the ADIGE, PIAVE and TAGLIAMENTO Rivers.

Deliberate flooding of the areas in the coastal deltas of the rivers emptying into the ADRIATIC SEA would be possible by breaching the river dikes in combination with natural high water conditions or with other artificial flooding operations. This type of flooding operation would be

especially effective on the ADIGE River below LEGNAGO where the river surface is always above the level of the adjacent land. Here, it is only necessary to breach the river levees at strategic points during periods of moderate to high stages and discharges in order to flood a large depression between the ADIGE and PO Rivers as well as the delta region between the ADIGE and BACCHIGLIONE Rivers. Also breaching of dikes and manipulation of irrigation and drainage systems during the rainy season or in combination with releases from reservoirs would cause shallow inundation of the widespread irrigated and reclaimed areas, as for example, the reclaimed land located on the right bank of the PIAVE River near its mouth.

Continuous military support of the temporary or permanent dam installations and navigation and irrigation control structures would be necessary to prevent their destruction by enemy air or ground action. Destruction or failure of a dam would release a flood wave of short duration that would temporarily prevent or harass crossing operations and might cause failure of other downstream structures. Breaching of permanent dams or damage to the operating mechanism would prevent useful operation of the gates, especially for cyclic wave operation. Such destruction by enemy action would also prematurely release flood waves that could hinder movements of our forces below the dams. Deliberate demolition of those structures would prevent their use by the enemy during a later critical period.

SPECIAL STUDY S-53-3

ARTIFICIAL FLOODING POTENTIALITIES
VENETIAN-FRIULI PLAINS OF NORTHEAST ITALY

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ARTIFICIAL FLOODING POTENTIALITIES
VENETIAN-FRIULI PLAINS OF NORTHEAST ITALY

SECTION I

INTRODUCTION

1-01 ASSIGNMENT

This study was assigned to the Military Hydrology Research and Development Branch, Engineering Division, Washington District, by letter from Office, Chief of Engineers, ENGWE, to the Division Engineer, North Atlantic Division: subject, "Military Hydrology R&D Project No. 8-72-12-001: Special Assignment" dated 9 January 1953.

1-02 PURPOSE AND SCOPE

a. This report presents information regarding the hydraulic effects and nature of artificial flooding potentialities in the VENETIAN-FRIULI PLAINS from the ISONZO to the ADIGE Rivers. The major river basins in the area are: the ISONZO, TAGLIAMENTO, LIVENZA, PIAVE, BRENTA, BACCHIGLIONE and ADIGE.

b. The study consists largely of a compilation and consolidation of information presented in various intelligence documents and technical publications, with certain supplementary analyses and discussions. The data and information forming the basis of this report were limited to that available in the Washington, D. C. area, or obtainable from other sources within the time allotted for the study. Detailed analyses were limited to factors considered to have the maximum military effect. A generalized qualitative evaluation was made of the less critical elements in order to determine their relative possibilities. A complete investigation of the entire area would require considerably more engineering data. Such an investigation probably would yield quantitative results which would furnish a more complete and detailed view of the artificial flooding potentialities of the VENETIAN PLAINS.

c. The report is designed to furnish basic data and results of analyses needed to answer questions concerning:

(1) Normal and extreme stages, discharges and velocities at key stations on the rivers in the VENETIAN PLAINS.

(2) Stream characteristics including gradients, depths, and widths of channel and flood-plain on those streams.

(3) Data concerning locations and zero elevations of gaging stations.

(4) Data concerning locations and dimensions of dams.

(5) The extent of flooding possible by erection of temporary dams or disruption of drainage and irrigation facilities.

(6) The magnitude and duration of flood waves and flow variations created by breaching or regulated discharge from the dams and reservoirs, and the effect on military bridging and crossing operations.

1-03 ARRANGEMENT

This report is sub-divided as follows:

Section I	Introduction
Section II	Drainage Basin Characteristics and Developments
Section III	Hydrologic Characteristics
Section IV	Artificial Flood Potentialities
Section V	Effect on Military Operations
Bibliography	
Tables	
Plates	
Exhibit A	Abstracts of Technical Literature on Hydraulic Developments in the VENETIAN-FRIULI PLAINS
Exhibit B	Gazetteer

1-04 DEFINITIONS AND REFERENCE DATUM

a. Equivalent English-Metric Terms. Most values used in this report are in the Metric System. Conversion factors for the English and Metric systems are presented for convenient reference in Table 1.

b. Hydrologic Terms and Abbreviations.

(1) The following abbreviations are used in this report:

cm	centimeters
mm	millimeters
m	meters
km	kilometers
l	liters
km^2	square kilometers
m^3	cubic meters
m^3/sec	cubic meters per second
hr	hour
m/sec	meters per second

(2) Standard Italian hydrologic terms, with the equivalent English terms in parentheses, are defined in Table 2.

c. Elevation Datum. All elevations referred to in this report are in meters above mean sea level (msl) of the Mediterranean Sea, the datum of the Italian "Instituto Geografico Militaire."

d. River Distances. In this report, distances are expressed in kilometers measured as follows:

(1) ISONZO, TAGLIAMENTO, and LIVENZA Rivers: map distances measured along the centerline of the channel from the mouth.

(2) PIAVE, BRENTA, and ADIGE Rivers: distance from the mouth based on river profiles contained in documents listed as References 2, 3 and 4 in the Bibliography of this report.

e. Maps. The drainage basins of the rivers of the VENETIAN PLAINS are covered by the following standard American AMS (Army Map Service) and British GSGS (Geographic Section General Staff) map series:

Scale	AMS Series	GSGS Series	Sheet Numbers
1:250,000	M591	4230	5, 6, 7, 7B, 12, 13
1:100,000	M691	4164	1, 1A, 2, 3, 4, 4A, 4B, 9, 10, 11, 12, 13, 14, 14A, 20, 21, 22, 23, 24, 25, 26, 26A, 35, 36, 37, 38, 39, 40, 40A, 40B, 48, 49, 50, 51, 52, 53, 63, 64, 65
1:50,000	M791	4229	Same as 1:100,000, each sheet divided into quadrants: I, II, III and IV
1:25,000	M891	4228	Same as 1:50,000, each sheet divided into quadrants: NE, SE, SW and NW.

f. Grid System. Grid references cited in this report are to the 1,000 meter "Universal Transverse Mercator" (UTM) Grid System unless otherwise designated.

g. Gazetteer. Geographic names and locations of places mentioned in the report are contained in a Gazetteer included as Exhibit B.

1-05 REFERENCES

All references cited in this report are listed in the Bibliography following Section V of the text.

SECTION II

DRAINAGE BASIN CHARACTERISTICS AND DEVELOPMENTS

2-01 GENERAL

a. The rivers of the VENETIAN PLAINS rise in the ALPS and flow generally southward through deep narrow gorges onto the broad, flat plains, emptying into the ADRIATIC SEA. The ALPS are the chief physiographic feature favoring hydroelectric power production in NORTH ITALY. Present hydroelectric developments have made ITALY practically self-sufficient in electrical energy. Locations of the major rivers and tributaries are shown on the map presented in the report as Plate 1.

b. This report is confined to consideration of the plains from the ISONZO westward to the ADIGE River. The mountain area is considered to the extent of examining the hydraulic effects produced in the plains by control structures located in the headwaters.

2-02 TOPOGRAPHY

a. General. The region is bounded on the north by the Alpine mountains, on the west by the MONTI BERICI and EUGANEAN HILLS, and on the southwest by the northern part of the PO delta. The area can be divided into three parts: the coastal zone, the low plain and the high terraces which border the mountain zone. Plate 2 is a physiographic diagram illustrating the general nature of the terrain and References 2 through 17 contain detailed topographic descriptions of the region. Exhibit A describes the region by river basin.

b. The coastal zone extends approximately 10 miles inland from the coast, and is indicated by the railway line which runs from MESTRE to PORTOGRUARO ad then eastward to the ISONZO River. This area contains two large shallow lagoons, the LAGUNA DI VENETA and the LAGUNA DI MARANO. The land is well drained between the two lagoons. Across this zone the rivers are regulated and restricted to single channels between high embankments. The SILE at one time flowed into the LAGUNA VENETA but is now diverted around the northeastern end of the lagoon in an embanked artificial course. The BRENTA has been similarly diverted around the southwestern end of the LAGUNA VENETA. The BACCHIGLIONE has had its entire lower course straightened, and the LIVENZA and PIAVE Rivers also have had much of their former meandering courses within the delta straightened and confined by levees.

2-02

c. The low plain rises gradually from the northern edge of the coastal zone to a line indicated approximately by the railroad from PIAZZOLA SUL BRENTA through TREVISO to PONTE DI PIAVE. From this point the boundary runs northeast to PORDENONE, then eastward through BAGNARIA ARSE to the ISONZO River. Across this area the main rivers meander in diked flat-bottomed channels. The PIAVE and TAGLIAMENTO Rivers enter the low plain in broad beds a mile or more wide with several channels flowing through a maze of sand and gravel. Below PONTE DI PIAVE and VARMO the braided beds become single navigable channels. East of the TAGLIAMENTO River, the northern edge of the plain is clearly indicated by a "fontanili" or "line of springs."

d. The high terraces rise more steeply than the low plain zone northward to a line indicated by the junction of the mountains and high terraces (see physiographic diagram, Plate 2). West of the LIVENZA the land is generally well drained except in the small areas between the hills which are found along the line of junction between the plain and the mountains. East of the LIVENZA, many of the rivers which come down from the mountains disappear into permeable gravels and are normally very dry. Here, the TAGLIAMENTO and MEDUNA Rivers flow in deep valleys a mile wide with braided courses. They are stoney and gravelly, and the sides of the channels rise 70 feet or more from the river bed to the terraces on either side.

2-03 GEOLOGY

The coastal plain has predominantly clay soils which are dry due to an extensive drainage and irrigation system. The low plain is composed of gently undulating sands and sandy clays which is generally dry. Irrigation is necessary and the whole area has an intricate pattern of irrigation channels. West of the LIVENZA River the high terrace is composed of sands and gravels with a capping of light clays. East of the LIVENZA River, the high terrace area is characterized by great fans of gravels extending from the mountain edge down to the southern limits of the area. Detailed information is contained in References 2 through 17. Reference is also made to paragraph A-03 of Exhibit A.

2-04 DRAINAGE AREAS

The total drainage area of the region from the ISONZO River to the ADIGE River is about 38,000 km^2, of which approximately 25,000 km^2 is mountain basin drainage. Drainage areas at key gaging stations are listed in Table 3. The gaging stations are designated by Serial Nos. G-1 to G-38 and are located on the general map, Plate 1. A tabulation of drainage areas for some of the major rivers follows:

2-04

River	Location Name	Gaging Station	Drainage Area
ISONZO	PIERIS	G-3	3,369
TAGLIAMENTO	LATISANA	G-13	2,300
PIAVE	PONTE DI PIAVE	G-21	3,763
BRENTA	SARSON	G-22	1,563
ADIGE	CAVANELLA	G-38	11,954

2-05 GRADIENTS AND PROFILES

River gradients are steep in the mountain regions and considerably more gradual below the points where the streams enter the plains region, as may be seen on the river profiles of Plates 3a to 3g. The high terraces, however, have considerable slope. The profiles presented do not in some cases include the river source but extend into the mountains only far enough to include any major hydraulic structures which may exert an effect on the plains area within the scope of this study. The relation of mountain stream slopes to those of the plains are, however, clearly indicated. A tabulation of average gradients of major streams follows:

River	Reach River Km	Average Gradient m/km
ISONZO	0-63	1.6
"	63-84	4.8
"	84-88	25.0
"	88-102	3.6
CORITENZA (Tributary)	102-118	25.0
" "	118-120	125
TAGLIAMENTO	0-45	0.1
"	45-139	4.2
LUMIEI (Tributary)	139-147	12.5
" "	147-157	50.0
LIVENZA	0-110	0.45
"	110-113	317
PIAVE	0-42	0.1
	42-172	4.0
	172-206	14.1
BRENTA	0-76	0.2
	76-120	3.1
	120-174	5.6
ADIGE	0-140	0.2
	140-338	1.3
	338-388	12.5
	388-399	48

2-06 CHANNEL DEPTHS

Depths of the streams are greatly influenced by large power dams in the head-waters and by numerous navigation and irrigation structures in the plains region. River gage heights are discussed in paragraph 3-03. Field investigations to determine the height of the gage zeros above the stream beds would afford ameans of determining river depths by analysis of the river stage records.

2-07 CHANNEL AND FLOOD-PLAIN WIDTHS

In general, the rivers of this area are narrow in the mountainous head-waters and are wider in the plains region. The PIAVE, MEDUNA and TAGLIAMENTO Rivers have braided channels where they enter the high terraces from the mountains, and are a mile or more in width. In the lower plains and delta regions, the rivers are confined by levees. In the lower plains where the rivers are leveed, the flood plains are limited to the complex systems of road and railroad embankments.

2-08 NAVIGATION

a. General. Internal navigation in Italy is of minor economic importance since it handles less than 5 percent of the total volume of freight traffic in Italy. This is not due necessarily to the waterway system itself, but rather to the excellence of the highway and railroad systems. This waterway system is, however, important from a military standpoint, not only for its utilization in defensive techniques but also as a line of communications from the coast to important inland industrial centers using small, shallow draft amphibious equipment. Principle navigable waterways are shown on Plate 1. The following information is based on Reference 19 and additional data may be found in References 16, 18 and 20. The total length of navigable rivers and canals in Italy is 1966 kilometers. The northern lakes accommodate 362 kilometers of passenger service. Excluding the lakes, the lengths of principle navigation systems in the VENETIAN PLAINS area are as follows:

	Km
VENETIAN COASTAL CANAL	440
VENICE-BRONDOLO-PO and POLESINE	278
ADIGE RIVER	172
VENICE-PADOVA-ESTE and BATTAGLIA BRONDOLO	150

b. The VENETIAN Coastal Canal, completed in 1918 as a main supply line for the Italian Army, is navigable for 600 ton barges for its entire length of 109 kilometers. Smaller barges not exceeding 300 tons can be accommodated by those rivers which flow to the ADRIATIC, including the SILE, PIAVE, LIVENZA, TAGLIAMENTO, STELLA, CORNO and the AUSA, all of which are connected to the Coastal Canal.

2-08

c. VENICE-BRONDOLO-PO-POLESINE Canal System. Barges of 600 tons can safely navigate approximately one-half of the 102 kilometers of canal network from the PO to the lagoon of VENICE consisting of the CHIOGGIA-BRENDOLO-PO Canal of 40 kilometers, the 15 kilometer LOREO Canal, and the GORZONE Canal for a distance of 47 kilometers. Small boats only can negotiate the LOREO Canal, while the water level must be high on the GORZONE Canal for even small boats to navigate.

d. The ADIGE River between CERAINO and CAVANELLA D'ADIGE, a distance of 172 kilometers, can accommodate small boats traveling down-river only because of the strong current and then only during high water.

e. The VENICE-PADOVA-ESTE and BATTAGLIA BRONDOLO canal network will support only small boat traffic for a distance of 150 kilometers. It is being modernized and deepened to accommodate 100 ton barge traffic.

2-09 REGULATION

The many hydroelectric power dams and reservoirs in the mountainous headwaters, and diversion structures for irrigation and navigation in the plains region materially influence the flow in the streams. The streams are torrential in character and vary considerably between high and low discharges. Constant supervision is necessary because of the constantly changing river beds. Channel rectification and confinement of the rivers to single channels in the lower plains and delta areas provide flood protection during periods of normal high water. Details of flood protection provided on the PIAVE, BACCHILIOGNE-BRENTA, and ADIGE Rivers are contained in References 2, 3 and 4 respectively.

2-10 DAMS AND RESERVOIRS

a. General. North Italy produces and uses far more electric power than any other part of the country. About 75 percent of Italian electric power production and almost the same amount of the country's total industrial capacity are in North Italy. Despite the abundance of water power, however, it has been difficult to regulate the rivers in order to obtain a constant supply. The construction of seasonal reservoirs on a scale without parallel has made Italy practically self-sufficient in electric energy. Detailed information on hydroelectric power production is contained in References 21 and 22.

b. Major Hydroelectric Dams and Reservoirs. The major dams creating reservoirs for hydroelectric power production are located on the head-waters of the rivers in the Alps and are characterized by relatively low flows and high heads. The power plants are generally in series, that is, the plant which derives its water from the reservoir supplies the next plant down-stream by means of a pressure conduit; thus, each plant draws its water from the discharge of the plant immediately above. In addition to the dams, many of the natural lakes, described in paragraph 2-13a contain considerable amounts of water available

for power. The largest of these, LAGO S. CROCE, has a storage capacity of 120 million m^3. Locations of major projects, designated as Serial Nos. R1 to R37, inclusive, are shown on the general map, Plate 1, and a summary of available data is presented as Table 4. Paragraphs A-04 to A-09 of Exhibit A contain descriptions of important power developments as translated and abstracted from technical literature. Additional information may also be found in References 17, 23 through 64, 76, 78, 79 and 80. Sketches of the dams considered in this study appear on Plates 8a to 8d. A tabulation of pertinent data on the dams considered in this study follows:

Dam	LUMIEI	PIEVE DI CADORE	S. VALENTINO	S. GIUSTINA
River	LUMIEI	PIAVE	ADIGE	NOCE
Serial No.	R-4	R-11	R-22	R-28
Storage ($10^6 m^3$)	72.8	64.3	110.0	182.2
Height (m)	136	55	32	150
Gates-Spillway	None	2-9x6.9	3-22 m dia.	2-9x4.5
Gates-Scour*	2-3.0x2.3 1-2.3x1.6	2	2	1-2.8x4.2 1-2.3x3.6

*For safety precautions, Italian Government regulations require the LUMIEI Dam type of sluice gates in the PIEVE DI CADORE, VAL GALLINA and S. GIUSTINA Dams because of ease in opening. This type of vertical-lift, double-gated outlet is detailed in Fig. 1 of Plate 8a.

c. Minor Dams.

(1) There are numerous small dams and weirs in the plains and coastal areas which divert the streams for purposes of power, navigation and irrigation. The operation of these low-head, run-of-river type of power plants is dependent upon the flow of water in the rivers. Since they do not store large quantities of water, they do not generally affect the river discharge except between the points of diversion and return. As in the case of the major power plants, discussed in paragraph 2-10b, the small power plants are characteristically in series, the plant downstream, being dependent upon the discharge of the upstream plant; however, instead of pressure conduits, the plants are inter-connected by open power canals. In some instances, water is diverted from these power canals to irrigated areas. The small plants, designated by Serial Nos. P-1 to P-5 on Plate 1, are only a few of the many existing small plants. These plants were included in the study only for possible supplementary discharge data. Additional information may be found in Reference 17.

(2) Except during periods of extreme high water and low water periods, navigable depths are maintained on the inland waterways discussed in paragraph 2-08 by weirs and locks. These same structures in many cases also divert water for irrigation. This dual type of diversion is discussed in paragraph 2-12 of this report.

2-11 LEVEES

Many of the rivers in their lower reaches in the plains and delta regions have had their courses straightened for navigation, and levee systems have been constructed for flood protection. Complete detailed data on the levees in the entire area considered in this study were not available. Additional information for the PIAVE, BRENTA and ADIGE Rivers may be found in References 2, 3 and 4, respectively.

2-12 CANALS

a. Italy does not have a network of inland navigation of the extent and importance of those found in France, Belgium, Holland and Germany for several reasons: orographic and geographic conditions; lack of mines, coal, etc., which produce the most tonnage of traffic on most waterways; and the excellence of the highway and railroad systems. With the exception of the VENETIAN Coastal Canal, the principal canals constructed in the VENETIAN PLAINS are for the dual purpose of navigation and irrigation.

b. These mixed canals do not have the characteristics of modern inland navigation canals as they are designed for the ultimate utilization of water principally for irrigation. They are designed almost exclusively to carry flows during periods of high water without regard to the types of craft which ply the canals, and without consideration of the traffic pattern or the junction points with other systems, all of which are elements considered in the planning of navigation canals. In the case of low-lying canals, it is necessary to drain the water from the reclaimed land to common collection points where it is pumped to the higher canal systems. These canals are in most cases supplied by rivers, springs or from rainfall. Main inland waterway routes are shown on Plate 1, and Plate 9 delineates the extent of irrigation and reclamation. Dual purpose canals are discussed in Reference 65 and details of irrigation canals are contained in Reference 66. Reference is also made to Exhibit A, paragraph A-06a(7), A-07, A-08 and A-09a(10).

2-13 LAKES, GLACIERS, LAGOONS AND MARSHES

a. <u>Lakes</u>. A number of lakes are located in the headwaters of the major streams which flow into the VENETIAN-FRIULI PLAINS. The lake bottoms lie much lower than the outlets which are usually small streams. Consequently, only a limited amount of the lake storage can be released. Some of the lakes are utilized for hydroelectric power production. The area and volume of some of these lakes with reference to pertinent paragraphs of Exhibit A describing hydroelectric power developments utilizing natural lakes are as follows:

2-13a

Lake (Lago)	River Basin	Area (km^2)	Volume (million m^3)	Exhibit A par.
CAVAZZO	TAGLIAMENTO	1.7	18	-
S. CROCE	PIAVE	-	120	A-06h
MORTO	PIAVE	-	3	A-06h
CALDONAZZE	BRENTA	5.4	141	-
LEVICO	BRENTA	1.1	20	-
CALDARO	ADIGE	1.5	-	-

b. Glaciers. The ADIGE River is the only stream in this area that has glaciers of any significance in the ALPINE headwaters. The ADIGE has 185 glaciers with a total area of 278 km^2.

c. Lagoons and Marshes. From VENICE, southward to the PO River, the coastal zone consists of off-shore sand bars which rise a few feet above sea level, behind which lie shallow lagoons generally not more than a foot deep, except for the channels which have been dredged for the VENETIAN Coastal Canal. Between the rivers in this region are areas of marsh, lagoon, or reclaimed land cut off from the sea by north and south parallel lines of sand dunes. The lagoons, surrounded by marshy ground, are gradually silting up. Much of this land on either side of the ADIGE has been reclaimed. Eastward from VENICE to the ISONZO River, the coastal area is also a region of shallow lagoons and marshes barred from the sea by an almost continuous line of dunes. In all respects it is similar to areas at the mouths of the BRENTA and ADIGE. Torrential rivers bring down masses of silt during flood periods, constantly adding land by deposition in the shallow lagoons. The accumulation of silt about the mouths of the ISONZO, TAGLIAMENTO and PIAVE has permitted reclamation of some of the area. East of the TAGLIAMENTO in the low plain region is a broad band of marsh land which extends southward from the line of springs almost to the northern edge of the coastal marsh and lagoon area.

2-14 BRIDGES

Reliable information concerning the present status of bridges was not available in this office; however, the bridge sites used in this study, as taken from maps, are indicated on the river profiles, Plates 3a through 3g. Pre-war bridge data is contained in References 7, 67, 68 and 69. Reference 70 is the partial completion of a road survey under way in 1949 and does not contain information in this particular area as of that date.

SECTION III

HYDROLOGIC CHARACTERISTICS

3-01 GENERAL

a. Data concerning river stage, discharge, flow duration and velocity are presented in generalized form as far as practical in order to facilitate the application of the data to specific military problems. The references cited should be used for supplementary data.

b. Available hydrologic records are fairly complete for the period 1922to 1946. Continuity of records has been hindered by changes in locations of gages, discontinuation of old and establishment of new gage sites and, in some cases, changes in gage zeroes.

3-02 CLIMATOLOGY

The rainfall regime of the area is mainly of the continental type. The heaviest rainfall occurs in the ALPS and the lightest in the lowlands. The prevailing direction of wet air masses is from the west; hence, more rain falls on the west side of the mountains than on the sheltered east side. Winter has the least amount of rainfall while spring and autumn are the wettest periods of the year. Several valleys in the ALPS have a single maximum in summer (July) a minimum in winter which is the exact reverse of the true Mediterranean type. There is permanent snow in the ALPS above elevation 8800 ft-9800 ft (2700 m-3000 m) above msl. In the northern plains snow is said to lay from 8 to 10 days. Snow even persists for several months in the Alpine valleys. Winters are damp and fairly cold in the plains, averaging 32° to 39° in January. VENICE has an average of 13 days of minimum temperatures below freezing in January. The summers are hot in the plains, with mean temperatures in July ranging from 75°-82°, but excessive heat is rare. Rainfall and temperature records for the VENETIAN-FRIULI PLAINS are published in References 71 and 72. Additional information on climate may be found in References 2, 3, 4, 11 and 16. The seasonal variation in precipitation is illustrated by the following table from Reference 16:

MEAN MONTHLY PRECIPITATION (INCHES)

	ALPS		ISTRIA	PLAINS			
	BOLZANO	BELLUNO	TRIESTE	UDINE	VICENZA	VENICE	PADOVA
Jan	1.0	1.9	2.2	2.6	2.8	1.4	2.1
Feb	1.0	2.2	2.3	3.1	3.1	1.7	1.9
Mar	1.7	3.7	2.8	4.6	4.2	2.1	2.4
Apr	2.2	4.1	2.9	5.4	4.7	2.2	3.0
May	2.8	5.5	3.7	5.9	5.5	2.8	3.4
Jun	3.2	5.2	4.1	6.9	4.7	2.9	3.4
Jul	3.8	4.5	3.7	4.8	3.0	1.9	2.5
Aug	3.6	4.1	3.7	4.9	3.5	2.0	2.6
Sep	2.8	4.8	4.0	6.5	4.9	2.6	3.0
Oct	3.1	4.8	4.7	7.0	5.7	3.7	3.8
Nov	2.1	3.0	3.6	4.8	4.4	2.2	3.3
Dec	1.3	2.8	3.4	3.7	3.4	1.6	2.5
Year	29.1	48.2	41.8	61.1	50.3	26.3	33.9
No. Years	16	25	24	25	25	25	-

3-03 STREAM GAGING STATIONS

Numerous stream gages have been established on the principal rivers and tributaries. Locations of key stations, designated by Serial Nos. G-1 to G-38, are shown on the general map, Plate 1, and on the stream profiles, Plates 3a to 3g. Stage records and other data for additional stations may be found in References 71 and 72. Pertinent gage data compiled from these references are summarized in Table 3.

3-04 RIVER STAGES

a. Records. The mean and extreme stages of record are tabulated in Table 3. The data shown were compiled from Reference 71 and cover various periods of record. As indicated in Table 3, some of the stations are influenced by tides and the operation of irrigation and navigation structures. The effect of normal operation of the small run-of-river hydroelectric plants is believed to be slight because they do not store large quantities of water. The major dams, however, which are under construction or which have been recently built in the ALPINE headwaters will have an appreciable effect on the downstream gages.

b. Stage variation. Seasonal stage variation is illustrated on the graphs of monthly mean stages presented on Plates 4a to 4e. With the exception of the ADIGE, the rivers of the VENETIAN-FRIULI PLAINS have two periods of maximum stages; one occurring in the late spring, the other in the late fall. The ADIGE has the characteristics of the ALPINE type, with the maximum stages occurring in June as a result of the melting of snow and glaciers in the ALPS during the spring. The ranges between high and low stages at representative stations are shown in the following tabulation:

3-04b

Stream	Station	Serial No.	Gage Heights (m) Maximum	Minimum
ISONZO	CANALE	G-1	10.60	0.66
TAGLIAMENTO	PIOVERNO	G-9	4.08	0.08
LIVENZA	FIASCHETTI	G-14	6.17	1.96
PIAVE	SEGUSINO	G-19	4.52	0.05
BRENTA	SARSON	G-22	4.65	-0.80
BACCHIGLIONE	VICENZA	G-25	5.56	0.18
ADIGE	ALBEREDO	G-34	2.70	-3.65

c. Stage duration. Stage duration curves for several key stations are exhibited on Plate 5. These curves show the percent of time that a given stage may be expected to be equalled or exceeded.

3-05 RIVER DISCHARGES

a. Records. There are very few discharge measuring stations within the VENETIAN-FRIULI PLAINS. Data for small hydroelectric plants, which are located on the general map, Plate 1, and designated by Serial Nos. P-1 to P-5, were extracted from Reference 17 to supplement the meager discharge information available in this area.

b. Stage-discharge relation. Average stage-discharge rating curves for certain stations are presented on Plates 7a to 7c. Insufficient basic data concerning discharge measurements and the channel characteristics (cross-sectional area, wetted perimeter, roughness, etc.) were available to accurately determine stage-discharge relation curves. These curves were estimated from the meager data contained in Reference 71 and from channel characteristics as taken from maps.

c. Discharge variations. Stream discharge follows the same seasonal pattern as the stage (see paragraph 3-04b). Mean and extreme discharges are included in Table 3 for stations where data were available and seasonal variations are presented on Plates 4a to 4e. The following tabulation illustrates the range in discharges at the stations within the plains region:

River	Station	Serial No.	Discharge (m^3/s) Maximum	Minimum
ISONZO	CANALE	G-1	1080	17.1
TAGLIAMENTO	PIOVERNO	G-9	2000	15.4
LIVENZA	FIASCHETTI	G-14	86.5	6.2
PIAVE	SEGUSINO	G-19	1200	17.9
BRENTA	SARSON	G-22	673	71.8
BACCHIGLIONE	MONTEGALDELLA	G-26	295	5.5
ADIGE	BOARA PISANI	G-36	1871	58.0

d. Discharge duration. The percent of time that a given discharge may be expected to be equalled or exceeded is shown on the duration curves of Plate 6. These curves were derived from data given in Reference 71.

3-06 RIVER VELOCITIES

a. General. River velocities vary according to the configuration of the river channel, depths, obstructions, restrictions, variations in slope, etc. Channel rectification, walls and levees, the operation of dams and diversion structures, and other alterations to natural conditions materially affect the stream velocity. Tributary rivers during flood tend to raise the elevation of the water in the main channel; consequently, correlations between velocity and river stage at gaging stations are not applicable at all points along the adjacent river reaches, but serve merely as indications.

b. Surface velocities. Estimated mean cross-sectional velocities were obtained by the methods used to determine stage-discharge relations discussed in paragraph 3-05b. These mean cross-sectional velocities were increased 18 percent to indicate the mean surface velocities. As discussed in Reference 83, the mean cross-sectional velocities should be increased by 25 to 75 percent to obtain the maximum surface velocities likely to be encountered during crossing operations. Estimated mean surface velocity curves are presented on Plates 7a to 7c. Mean surface velocities at selected stations for mean water and maximum natural flood conditions are tabulated below to give a general indication of stream velocities:

River	Station	Serial No.	River Km	Mean Surface Velocity (m/sec) Mean Stage	Maximum Stage
TAGLIAMENTO	INVILLINA	G-8	130	0.5	1.0
TAGLIAMENTO	PIOVERNO	G-9	109	1.5-2.0	3.5
PIAVE	SEGUSINO	G-19	95	0.5-1.0	1.5-2.0
ADIGE	TRENTO	G-31	253	0.5-1.0	1.0
ADIGE	PESCATINA	G-33	168	1.0	1.5

c. Flood wave travel time. The rate of travel of various flood peaks varies considerably. The estimated average rates of travel tabulated below are based on data in Reference 4 for 6 floods that occurred on the ADIGE in 1926 and 1928. The travel times listed for the other rivers are based on data contained in Reference 71 for 3 floods that occurred in 1928.

3-06c

River Reach	Serial No.	River Km	Average Travel Rate of Peak (km/hr)
ISONZO R.			
CANALE-PIERIS	G1-G3	52-9	6
TAGLIAMENTO R.			
PINZANO-LATISANA	G10-G13	89-32	4
LIVENZA R.			
FIASCHETTI-S. CASSIANO	G14-G16	103-79	1
S. CASSIANO-MOTTA	G16-G17	79-45	3
PIAVE R.			
SEGUSINO-NERVESA	G19-G20	95-64	4
BRENTA R.			
LIMENA-CORTE	G23-G24	67-26	7
ADIGE R.			
PONTE-TRENTO	G28-G31	312-253	9
TRENTO-PESCATINA	G31-G33	253-168	8
PESCATINA-BOARA PISANI	G33-G36	168-51	7

SECTION IV
ARTIFICIAL FLOODING POTENTIALITIES

4-01 GENERAL.

a. The term "artificial flood" as used in this report applies to any major increase in the extent of flooding, over that normally prevailing with existing developments, that is brought about by manipulation of control structures, breaching of dams or levees, or temporary damming operations designed to create flooding conditions. Applications of artificial flooding considered in this report fall into the following four general categories:

(1) <u>Still-water barriers</u>, created by flooding land to form water obstacles, using such means as breaching levees, diverting flow from canals, raising crests of existing dams or constructing temporary dams.

(2) <u>Drainage obstacles or mud-flats</u>, in which the wetness of the soil is increased to form muddy or marshy conditions which would impede military traffic, brought about by disrupting the normal drainage, destroying pumping and drainage facilities used to drain marshy or low land, or by inducing shallow inundation of flood-plains or reclaimed land. Mud-flats may also be formed by draining areas normally inundated by reservoirs or ponds.

(3) <u>Stream flow variations</u>, in which changes in discharges, depths, velocities and widths of streams are brought about to hinder stream-crossing operations or navigation such as might be accomplished by opening and closing outlet works of water control structures.

(4) <u>Major flood waves</u>, created by sudden breaching of a dam to release large quantities of impounded water.

b. Certain opportunities exist for effective use of these artificial floods on the streams of the VENETIAN-FRIULI PLAINS of Northeast Italy covered by this report. This section presents a review of the potentialities and a quantitative evaluation of the hydraulic effects. Reference should be made to Section V for discussion of associated military factors.

c. A measure of the possible extent of artificial flooding is the extent of natural floods experienced in a river basin. The flood of 1882 was the greatest experienced in this area, especially along the LOWER ADIGE River. Reference is made to the document listed as Reference 4 and to paragraph A-09g of Exhibit A of this report for description of the effects of this flood. Plate 10 shows the zone inundated along the ADIGE River during this flood. The natural and artificial levee breaks also indicated on that plate might serve as indications of likely locations for levee breaching in connection with artificial flooding operations.

d. A comprehensive detailed study of potential deliberate inundation of areas in the NORTH ITALIAN PLAIN by means of diversion of natural stream flows is contained in an Inter-Service Topographical Department Study (ISTD/K/391), listed as Reference 9 in the Bibliography of this report. That cited study considers the possibilities of inundation by diversion of natural stream flow through levee breaks and breaches during periods of moderate and high discharges; but it does not include study of possibilities of artificial augmentation of stream discharges or stages as considered in this report. Reference should be made to that ISTD study for supplementary information on locations and extent of potential inundation.

e. The use of artificial inundation in actual military operations is illustrated in "Le Piene dei Fiumi Veneti e i Provvedimenti di Difesa-il Piave," listed as Reference 2 in the Bibliography of this report. Chapter 10 of this reference discusses the effect of rivers on the war in northeast Italy during 1915-1918 and the Battle of the PIAVE. This article states that because effective entrenchments for stopping the enemy advance were entirely inadequate, the Military Hydraulic Officer of the Supreme Command (Italian Army) in cooperation with the Magistrate of Rivers (Civil) flooded the entire area between the channels of the PIAVE, old PIAVE and SILE Rivers. Details of how or where this deliberate flooding was accomplished are not given in this reference.

4-02 STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. General. The studies reviewed in this paragraph pertain to artificial flooding produced by still-water barriers and drainage obstacles at selected points on the VENETIAN-FRIULI PLAINS of Northeast Italy. The studies were largely based on a map study using 1:25,000 maps supplemented with high altitude aerial photographs. Exact determination of elevations, contours and boundaries was not possible; however, the results of the study are believed to offer good indications of the relative possibilities of such flooding at typical locations on the major rivers in the area. First-hand information should be obtained by local reconnaissance regarding ground elevations and the locations, elevations and dimensions of levees, roadfills and culverts in the vicinity of specific sites in order to accurately establish the area subject to artificial flooding.

b. Hydrologic Considerations.

(1) The effect of artificial flooding is largely contingent upon the hydrologic conditions prevailing at the time of the operation. The volume of water stored and available in the basin, the river stage and the rate of flow of the stream are important factors. Reference is made to Section III for detailed descriptions of the conditions to be expected.

(2) Attention is directed to the wide range between high and low flows and to the seasonal variations in flow in the rivers

crossing the ITALIAN PLAIN. Reference is made to Section III of the report, to paragraph A-03j of Exhibit A, and to plates 4 and 6 for details of these variations. Higher floods may be expected in spring and autumn than in summer or winter. During dry periods, flow often disappears underground in the region of permeable alluvial moraines near the foot of the mountainous region and reappears farther downstream. The range of mean and extreme discharge as given in Exhibit A are presented below to illustrate the possible range of discharges to be expected.

River	Discharges (m^3/sec) HHW	MW	LW
ISONZO	1200	40	13
TAGLIAMENTO	1500	80	50
PIAVE	3000	60	40
BRENTA	1035	140	25
BACCHIGLIONE	770	78	38
ADIGE	2500	220	100

c. Means of creating Still-water barriers and drainage obstacles.

(1) The water obstacle afforded by the rivers and canals of the VENETIAN-FRIULI PLAINS could be increased by utilization of one or more of the following means:

(a) Creation of still-water barriers by construction of temporary dams at bridge-sites, combined with closing of culverts and other openings in levees and embankments in the area.

(b) Inundation of the lowlands along the stream by breaching levees and by opening of flood gates in levees.

(c) Inundation of lowlands by interfering with their natural or artificial drainage or irrigation facilities.

(2) Due to the large number of potential sites in this extensive area and to the scarcity of specific detailed topographic and bridge data, the scope of this phase of the study was limited to sites affording the greatest potential flooding possibilities. Emphasis was placed on creation of still-water barriers at bridges along the two major east-west railroad lines crossing the area, namely: the VERONA-VICENZA-TREVISO-UDINE-GORIZIA line and the railroad closer to the coast through MANTOVA-PADOVA-TRIESTE. It is believed that effects at these sites would afford good indications of potential effects at other sites along the same rivers. The height of temporary dams considered was arbitrarily selected as 3-4 m above mean water (MW) as a reasonable maximum height to afford a basis of comparison of effects at various sites.

Where breaching of levees was involved, the estimate of resulting flooding of lowlands was taken on the conservative side. It was also assumed that the pools formed would be level and that mean water conditions would prevail at the time of the operation. During times of high flows, the water surface gradient could be expected to result in greater flooding than estimated in this study.

(3) Deliberate inundation would also be possible along the delta sections of the ISONZO, STELLA, TAGLIAMENTO, LIVENZA, PIAVE, SILE and BRENTA, as the streams in that coastal region lie below the level of the surrounding country. A similar condition exists on the ADIGE River below VERONA. However, the entire plains north of the PO River lie above sea level. Therefore, any flooding there would have to be effected by diversion of water from the streams through breaches in the embankments rather than by flooding from the ADRIATIC SEA. Reference is made to the document listed as Reference 9 for additional information.

d. Effect of still-water barriers.

(1) General. The effects of still-water barriers at typical points are summarized in Table 5 and the extent of inundation is illustrated on Plate 11. The areas indicated on Plate 9 as irrigated or reclaimed areas also offer possibilities for shallow inundation by means of disruption of normal drainage facilities. As illustrated on Plate 11, the ADIGE River offers the only possibility of the formation of a continuous barrier. Formation of continuous barriers on the ISONZO, TAGLIAMENTO, LIVENZA, PIAVE and BRENTA Rivers is not considered practicable except in their extreme lower delta region. The appreciable north-south slope and general flat east-west slopes of the terrain in the plains along these rivers would cause pools formed behind temporary dams to spread transversely rather than along the rivers. Review of the effects of still-water barriers and drainage obstacles on the rivers of the VENETIAN-FRIULI PLAINS of Northeast Italy follows.

(2) ISONZO River.

(a) At the PAPARIANO RR Bridge, Km 10 (Site No. 1 on Table 5 and Fig. II, Plate 11), it would be possible to form an isolated pool by raising a temporary dam to elevation 9.5 m (approximately 3m + MW). If the levees were left intact, the pool formed would be about 1/2 km long and 3/4 km wide with a maximum overbank depth of 3/4 m. If the right levee were breached when the stage was raised to 9.5 m, flow could be diverted along the RR embankment for 1.5 km to a low spot along the embankment (elevation 9.0) where it then could flow downstream behind the right bank levee to form a pool at elevation 9.0 between the right levee and the embanked road 3/4 km west of the right bank. By raising the temporary dam to elevation 9.5, combined with breaching the right levee and sandbagging this low point on the RR line, it would be possible to form a pool with an area of 4 km^2 and a maximum depth of 1.5 m.

4-02d

(b) Pools of the same type could probably be formed at other bridge sites on the ISONZO below GORIZIA. As stated above, pool lengths would be short along the river and would show a tendency to spread transverse to the river. It would be necessary, therefore, to find sites where embankments parallel to the river would confine the pool in this transverse direction.

(c) As shown on Plate 9, the left bank of the ISONZO below GRADISCA is irrigated from the river, an area about 10 km long by 5 km wide is involved. Formation of a drainage obstacle might be possible by means of manipulation of the irrigation and drainage facilities in this area.

(3) TAGLIAMENTO River.

(a) From the point where it enters the plain near PONTE DI PINZANO (Km 89) to the vicinity of RONCHIS (Km 40), the TAGLIAMENTO flows between levees 1-2 km apart. The river itself flows through this wide area in a complicated pattern of small interlaced channels. These channels are, in general, small and would appear to offer little or no natural obstacle to crossing at periods of low or mean water.

(b) The river bed in the vicinity of the RR bridge at Km 32 near LATISANA, shown as Site No. 2 on Figure IV of Plate 11, appears to be entrenched below the plain. Levees also seem to be low in this vicinity. Therefore, this location is not considered suitable for creation of an effective still-water barrier. However, breaking of levees in the reaches downstream from LATISANA could inundate areas up to 3 km on each side of the river during periods of above normal stages, according to Reference 9.

(c) The reach upstream from LATISANA to RONCHIS, Km 40, appears to be entrenched; consequently, formation of effective still-water barriers by erection of temporary dams is considered impracticable.

(d) At CASELLO (Km 59) Site No. 3, it would be possible to inundate the flood plain between the levees by raising a temporary dam to elevation 50 (approximately 4 m above mean water). This would form a pool 1.0 km long, 1.5 km wide, and with a maximum depth of 3 m and an average depth of 1 m. If the pool level were raised above 50 m, the left levee could be overtopped and flow diverted downstream behind the left levee. This diverted flow would form a series of pools behind various low secondary embankments along the left bank below the temporary dam site as indicated in Table 5 and on Figure IV of Plate 11. Temporary damming operations at other sites in this reach would probably result in similar pools.

(e) Above CASELLO a considerable area of the left bank is irrigated as indicated on Plate 9. Manipulation of irrigation and drainage facilities in this area would probably result in the formation of a shallow drainage obstacle.

(4) LIVENZA River.

(a) The reaches downstream from the railroad at S. ANASTASIO (Km 34), have a considerable amount of reclaimed and irrigated land along the right bank covering an area about 15 km long by 10 km wide as indicated on Plate 9. Interference and manipulation of the drainage facilities in this area would probably form an effective drainage obstacle.

(b) Formation of a still-water barrier at S. ANASTASIO, (Site No. 4 in Table 5 and Fig. III of Plate 11) does not appear practicable due to the entrenched nature of the river in this locality.

(c) At MOTTA DI LIVENZA (Km 45), Site 5, it would be possible to form a pool 1.0 km^2 in area by breaching both levees and raising a temporary dam to elevation 7.0 m (see Table 5 and Fig. III of Plate 11). By breaching both levees, two road embankments and a RR embankment on the left bank, the flooded area could be extended to cover an area of 2.5 km^2 with a maximum depth of 1.5 m. In addition, it might be possible to divert the flow behind the left levee causing the formation of a drainage obstacle between the river and the CANALE MALGHER.

(5) PIAVE River.

(a) On the PIAVE River the slope of the ground is such that a condition exists similar to that on the ISONZO in which the pools would tend to spread transverse to the river rather than along the stream and the main problem would be to confine this lateral flow to prevent its dispersion to other drainage channels.

(b) As mentioned in paragraph 4-02d(4), the area between the LIVENZA and the PIAVE Rivers and below the S. DONA DI PIAVE-S. ANASTASIO RR Line is shownon Plate 9 to be mostly reclaimed land and could probably be used as an effective drainage obstacle. Breaching gaps in the river banks in the delta region could inundate areas reaching as much as 6 km from the river according to Reference 9. Another large irrigated area lies on the right bank covering practically the entire 20 km portion between the two east-west railroad lines and extending about 30 km toward the BRENTA River. Manipulation of the irrigation and drainage works in these areas could probably be utilized to form a shallow drainage obstacle.

(c) At S. DONA DI PIAVE (Km 23), Site No. 6, it would probably be possible to flood the area between the road embankments lying 1 km either side of the river. Determination of length, depth and area was not possible due to lack of specific information at this site. Consequently, no indication of possible extent of flooding at Site No. 6 was shown on Figure V of Plate 11.

(d) At Site No. 7, located at the PONTE DI PIAVE railroad bridge at Km 43, it would be possible to flood an area 3 km long between the levees by raising a temporary dam to elevation 8.0 m (see Table 5 and Fig. V of Plate 11). The depth of this pool would probably be less than 1 m.

(e) Farther upstream at Site No. 8, Km 60, erection of a temporary dam at the PRIULA railroad bridge to elevation 69, combined with breaching the right-bank levees would create a still-water barrier 1.0 km long by 2 km wide with a maximum depth of 3 m.

(6) BRENTA River.

(a) Four possible sites for still-water barriers at railroad bridges on the BRENTA River were studied. These were Site No. 9 at PONTE DI BRENTA (Km 44), Site No. 10 at PADOVA (Km 49), Site No. 11 at CAMPO S. MARTINO (Km 72), and Site No. 12 at FONTANIVA (Km 86). Relative locations of these sites are indicated on the key map of Plate 11. At all of these sites, the river appears to be entrenched. Therefore, formation of still-water barriers by temporary damming operations was considered impracticable.

(b) As shown on Plate 9, a considerable area about 20 km long and 30 km wide east of VICENZA is irrigated. Manipulation of the irrigation and drainage works in this area would probably result in the formation of a shallow drainage obstacle of considerable extent.

(c) During periods of high water, cutting of embankments at any point below STRA (near PADOVA) would inundate land for up to 1 km or so on each side of the river, according to Reference 9.

(7) ADIGE River.

(a) As stated in paragraph 402-d(1) and shown on Plate 11, the ADIGE River offers the only possibility of the formation of a continuous barrier. On the ADIGE below LEGNAGO, Km 96, the water level is at all times above the level of the surrounding ground. In this region, it is only necessary to breach the river levees at strategic points during times of moderate to high stages and discharges to inundate much of the area lying between the ADIGE and PO Rivers as well as the delta sections between the ADIGE and BACCHIGLIONE Rivers. Reference is made to Plates 9, 10 and 11 for illustration of the possible extent and to Plate 10, paragraph A-09g of Exhibit A, and to References 4 and 9 for locations of likely points of levee breaching to cause such flooding.

4-02d(7)

(b) Below CAVARZERE, Km 25, the level of the ground is generally near or below sea level and the area could probably be flooded by tidewater if the river dikes were breached.

(c) Between CAVARZERE and LEGNAGO study was made of the possibility of flooding on the right bank. As shown on Table 5 and on Fig. 1 of Plate 11, a series of pools could be formed varying in width from 1 to 6 km. This represents a minimum condition to be expected at periods of mean or low water. In periods where sufficient volumes are available, it would probably be possible to inundate the entire area between the ADIGE and the PO Rivers as indicated in Reference 9. In addition to the right bank flooding illustrated on Plate 11, it is probable that a similar type of flooding could be accomplished on the left bank. Analysis of possible flooding in this flat region would be contingent upon availability of detailed data concerning elevations and locations of levees and other terrain features. Large scale topographic maps supplemented by local field reconnaissance would be necessary to secure such data.

(d) As shown on Plate 9, there are extensive irrigated and reclaimed areas in the vicinity of the ADIGE, extending for nearly 200 km to well above VERONA. Practically the entire 10 to 20 km wide strip between the ADIGE and PO Rivers consists of low-lying reclaimed land. Manipulation of the drainage and irrigation works in these areas would probably result in the formation of extensive drainage obstacles. The document listed as Reference 9 contains considerable detailed discussion of potential inundation of this region.

e. Water requirements for still-water barriers.

(1) The volume of water required to create the still-water barriers at suitable sites along the streams covered by this report described in the preceding paragraphs and shown in Table 5 and on Plate 11, together with the estimated time required for filling at the average rates of flow during MW periods given in paragraph 4-02b(2) are approximately as follows:

River	Site No.	Water Required (million m^3)	Approximate Filling Time (days)
ISONZO	1	2.1	0.5
TAGLIAMENTO	2	(Site not suitable)	
	3	3.5	0.5
LIVENZA	4	(Site not suitable)	
	5	2.6	-
PIAVE	6	(Volume not estimated)	
	7	3.0	0.5
	8	3.0	0.5
BRENTA	9-12	(Sites not suitable)	
ADIGE	13	60	3.0
	14	36	2.0
	15	36	2.0
	16	5	0.2
	17	22	1.0
	18	5	0.2
	19	15	1.0

(2) Under low water conditions, it would require approximately three times as long to fill the still-water barriers as shown in the preceding table for mean water conditions. During high water, the required time would be considerably reduced.

(3) Water stored in the hydroelectric reservoirs of the basin listed in Table 4, could be used to supplement natural flow for filling of still-water barriers. Under normal conditions, emptying of the reservoirs would take from 2 to 6 days. The time of travel would vary with the distance from the damsite to the location of the still-water barrier and with the hydraulic characteristics of the streams. The rate of travel would vary from about 3 to 8 km/hr in the upper reaches and from 2 to 5 km/hr in the lower reaches of the streams. As a rough approximation, it is estimated that travel time from the region of the reservoirs to that of the still-water barriers would be about 1 day in the TAGLIAMENTO, 2 days in the PIAVE and 2 to 4 days in the ADIGE basin. The following tabulation shows that the total capacity of the reservoirs in respective river basins is sufficient to fill the still-water barriers listed in Table 5, but probably might be insufficient if more sites were added or water were permitted to be diverted to other basins.

River Basin	Total Reservoir Storage (million m^3)	Still-water Barrier Volume (million m^3)
ISONZO	7.9	2.1
TAGLIAMENTO	72.8	3.5
LIVENZA	131.0	2.6
PIAVE	81.6	6.0
BRENTA	0.2	0
ADIGE	441.8	179

4-03 STREAM FLOW VARIATIONS

a. General. This paragraph pertains to the artificial flow variations along the TAGLIAMENTO, PIAVE, and ADIGE Rivers produced by release of water from the regulated outlets of LUMIEI, PIEVE DI CADORE, S. VALENTINO and S. GIUSTINA Dams, designated respectively as R-4, R-11, R-22 and R-28 on Plate 1 and in Table 4. Since their reservoir capacities rank among the largest in the region, the effects of outlet releases from these structures are most critical. Releases from outlets of the smaller reservoirs listed in Table 4 could be expected to give flow variations of lesser significance. Considerable additional engineering data and time would be required to complete a comprehensive investigation of the potential flow variations that could be produced by releases of water from the outlets of all the dams within the region. Reference is made to paragraph 2-10 and to Exhibit A for description of the dams studied, to Plate 1 for locations, to Plates 8a through 8d for sketches of the structures, and to Table 4 for summary of dam data.

b. Hydrologic Considerations.

(1) The initial river stage and discharge existing at the time of release of discharge from a dam greatly influence the effects. Flow conditions in the streams of the region vary considerably with the seasons and are influenced by the operation of irrigation, drainage and hydroelectric projects as discussed in Section III and Exhibit A. The initial or base stream flows at the start of the artificial flow variations as assumed for purposes of this study, approximate normal mean water conditions.

(2) Reservoir stage and storage also influence the effectiveness of outlet releases. No information was available regarding the seasonal variation of specific reservoirs. However, the pools probably could be expected to be full in late spring and autumn and partly full during the summer and winter. In this study all reservoirs were assumed as being full. The effects of outlet discharges when the pools are partly full would be appreciably less in both magnitude and duration than for full pool conditions. Reservoir storage capacity curves on Plate 12 for the four dams used in the study were estimated on the basis of meager data contained in the references cited in the dam summary of Table 4. These estimated storage curves were developed by the method presented in Reference 84 in which storage may be expressed as:

$$S = CH^n$$

where S = storage volume (m^3)
C = a coefficient
H = reservoir depth (m)
n = an exponent representing: $\frac{H}{h}$

where h = average depth representing: $\frac{\text{volume at H}}{\text{surface area at H}}$

The values of "C" and "n" as computed from available data for the four reservoirs follow:

Reservoir	Serial No.	S $10^6 m^3$	H (m)	C	n
LUMIEI	R-4	72.8	120	8.6	3.33
PIEVE DI CADORE	R-11	64.3	63.7	2,140	2.48
S. VALENTINO	R-22	110.0	27.5	496,000	1.63
S. GIUSTINA	R-28	182.2	125	9,600	2.53

(3) The possibility of cyclic releases from the reservoirs depends upon the rate of refilling of the depleted storage. A tabulation of estimated storage capacities and estimated average refilling times under assumed normal mean water conditions follows:

Reservoir	Serial No.	Pool Stage (msl)	Estimated Storage (million m^3)	Mean Inflow (m^3/sec)	Filling Time Days
LUMIEI	R-4	980.0	72.8	4	210
PIEVE DI CADORE	R-11	683.5	64.3	20	37
S. VALENTINO	R-22	1496.8	110.0	16	80
S. GIUSTINA	R-28	530	182.2	28	76

(4) During the downstream passage of an artificial flow variation or flood wave, an appreciable volume of water is retained behind embankments, in depressions on the flood plain and in low spots of the stream channels or lost through evaporation or seepage. For example, 39.5 percent of the water discharged from the EDER DAM breach of May 1943 was lost in passage of the flood wave to INTSCHEDE, 426.6 km below the dam (see Refs. 85 or 86). As discussed in paragraph 2-02, many streams crossing the VENETIAN-FRIULI PLAIN have reaches where the permeability of the channel and valley is rather high. Consequently, in this study it was assumed that 1 percent of the volume of discharge would be lost or retained for each 10 km of travel.

(5) Insufficient data were available on the smaller reservoirs located downstream of the four dams considered in this study, to permit quantitative evaluation of their effect upon artificial floods caused by releases from the upstream dams (see Plates 1 and 3a to 3g). The discharge capacities of the outlets of dams located on the same stream are probably similar. In most cases the downstream dams have relatively small reservoir capacities. For example, the combined capacities of MOLLARO (R-29) and ROCHETTA (R-30) reservoirs are only 3.9 million m^3 contrasted to a storage capacity of 182.2 million m^3 in S. GIUSTINA (R-28) reservoir, located immediately upstream. Consequently, in order to facilitate computations within the time limit allotted to the study, it was

assumed that the discharge capacities of the downstream reservoirs were sufficient to pass the artificial floods from the large upstream reservoirs without appreciable change.

c. Means of creating detrimental flow variations. Sudden opening of the regulated outlets (and gated spillways in some cases) would produce detrimental flow variations downstream from a dam. The magnitude of the discharge depends primarily upon the size and type of the outlets and their elevation relative to the reservoir pool elevation. The duration depends upon reservoir storage and upon the length of time that outlets are open. In this study, it was assumed that the outlets were suddenly fully opened when the pool was full and left open until the reservoir was emptied. This represents the maximum condition for flow variations. Reference is made to Plates 8a to 8d for sketches of the dam structure and to Plate 12 for the estimated outlet discharge rating curves for the four dams considered in this study. The curve for LUMIEI Dam (R-4) was based on fairly adequate data and may be considered as reasonably correct. The curves for the other three dams represent approximate estimates based on meager available data contained in Exhibit A. The following tabulation summarizes the estimated peak discharges from the fully opened outlets under full pool conditions:

Dam	Serial No.	Pool Stage (msl)	Estimated Discharge (m^3/sec)	Outlets
LUMIEI	R-4	980.0	610	1 emergency and 3 scour outlets
PIEVE DI CADORE	R-11	683.5	500	2 scour outlets
S. VALENTINO	R-22	1496.8	430	2 outlets
S. GIUSTINA	R-28	530	1000	Spillway and 2 scour outlets

d. Effects of detrimental flow variations.

(1) General. The effects of detrimental flow variations along the TAGLIAMENTO, PIAVE and ADIGE Rivers produced by releases from the outlets of the four dams considered are summarized in Table 6. Representative resulting discharge hydrographs at key locations and peak discharge profiles appear on Plates 13a to 13c. The flow variations are designated for purpose of identification as follows:

Artificial Flood No.	River Basin	Dam	Serial No.	Outlets
1	TAGLIAMENTO	LUMIEI	R-4	1 emergency and 3 scour outlets
2	PIAVE	PIEVE DI CADORE	R-11	2 scour outlets
3	ADIGE	S. VALENTINO	R-22	2 outlets
4	ADIGE	S. GIUSTINA	R-28	Spillway and 2 scour outlets

(2) Artificial Flood No. 1 represents the flow variation in the TAGLIAMENTO River created by sudden full opening of the three scour outlets plus the emergency outlet of LUMIEI Dam (R-4) shown on Plate 8a and described in paragraph A-05c of Exhibit A. The reservoir was considered to be at the full pool stage of 980.0 m above msl at the moment of gate opening. Gates were considered as being left fully opened for the entire 55 hours required to empty the reservoir. The initial discharge from the outlets of 610 m^3/sec would cause an increase of 450 m^3/sec above base flow at PASSO CANUSSIO (G-11), 108 km downstream from the LUMIEI Dam. River stage at PASSO CANUSSIO would be increased 2.0 m during the passage of the peak flow. The long flat peak of the flow variation is illustrated by the discharge hydrographs plotted on Plate 13a. The profile of peak discharge shown on that plate is also practically flat. These are characteristic of flow variations created by outlet releases from a reservoir of large storage capacity. Reference should be made to Table 6 for summary of effects on discharge, velocity and the extent and duration of the resulting flow variation at key locations along the TAGLIAMENTO River. Extracts of pertinent effects from that table at key locations follow:

PEAK VALUES - FLOOD NO. 1

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surface Vel. m/sec	Duration above bank days
G-8	2.5	1.0	0.7	1.0	2.0
G-10	3.5	Bankfull	0.2	1.2	0
G-11	4.0	0.5	0.4	1.2	1.5

(3) Artificial Flood No. 2 involves sudden full opening of the two scour outlets in PIEVE DI CADORE Dam (R-11) at a full pool stage of 683.5 m above msl. Location and dimensions of the outlets are indicated on Plate 8b and described in paragraph A-06d(2) of Exhibit A. The resulting peak discharge of 500 m^3/sec from the outlets would gradually decrease for about 48 hours and then drop sharply as the major portion of the reservoir storage became exhausted. As indicated on Plate 13b, the resulting flow variation along the PIAVE River would have a long flat crest with only slight reduction in peak discharge as the flow progressed downstream. At PONTE DI PIAVE (G-21), about 135 km below the dam, the increase in discharge would be 340 m^3/sec and the increase in stage would be 1.0 m above the values at initial base flow conditions at that location. Effects at selected key locations taken from the summary of effects presented in Table 6 follow:

PEAK VALUES - FLOOD NO. 2

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surface Vel. m/sec	Duration above bank days
BELLUNO	6.5	2.5	0.2	1.5	2.0
G-20	2.0	Bankfull	0.7	1.0	0
G-21	3.5	0.5	1.5	0.7	2.0

(4) Artificial Flood No. 3 is the flow variation on the ADIGE River resulting from full sustained opening of the two scour outlets of S. VALENTINO Dam under initial full pool conditions with the reservoir stage at elevation 1496.8 m above msl (see Plate 8c for sketches and paragraph A-09c(2)(a) of Exhibit A for description of the outlets). The initial peak discharge of 430 m^3/sec would drop slowly to empty the reservoir in about 130 hours. The flow variation would have a long flat crest as indicated on Plate 13c. Peak discharge at ALBEREDO D'ADIGE (G-34), 285 km below S. VALENTINO Dam would be 465 m^3/sec, representing an inrease of 215 m^3/sec above the assumed 250 m^3/sec initial base flow at that location. The stage would be raised only about 0.5 m above base flow conditions at that station and would not appreciably exceed bankfull conditions for most of the distance fownstream from the dam. Reference is made to Table 6 for summary of effects. The following tabulation presents extracts from that table at selected key locations:

PEAK VALUES - FLOOD NO. 3

Station No.	Stream Depth m	Overflow Height m	Width Flooded Km	Mean Surface Vel. m/sec	Duration above bank days
G-28	6.5	Bankfull	0.1	1.1	0
G-31	4.0	Bankfull	0.3	0.9	0
G-33	3.0	In banks	0.2	1.3	0
G-34	3.0	Bankfull	0.6	0.7	0

(5) Artificial Flood No. 4 involves flow variation on the NOCE and ADIGE Rivers created by sudden opening of the gated spillway and two scour outlets of S. GIUSTINA Dam (G-28) on the NOCE River. Considering initial full pool conditions at elevation 530.0 m above msl, the initial peak discharge of 1000 m^3/sec would decrease to approximately 625 m^3/sec in 6 hours, at which time the pool would have dropped to the spillway crest elevation. Discharge continuing through the outlets would practically empty the reservoir in about 7 days. The spillway and outlets are indicated on the sketches of the dam*/and are described in paragraph A-09e(3)(a) of Exhibit A. As discussed in paragraph 4-03b(5), it was assumed for purposes of this study that the influence of the two small downstream reservoirs (R-29 and R-30, shown on Plates 1 and 3g) upon the flow variation from S. GIUSTINA Dam (R-28) would not be appreciable. The flow variation of Flood No. 4 would attain a peak discharge of 640 m^3/sec at ALBEREDO D'ADIGE (G-34), 180 km below the S. GIUSTINA Dam. This corresponds to an increase above base flow conditions of 390 m^3/sec in discharge or 1.0 m in stage. The long flat crest indicated on the discharge hydrographs of Plate 13c is characteristic of flow variations created by sustained outlet releases from a large reservoir. As indicated in Table 6 and on Plate 13c, the effects of this flow variation in the lower reaches of the ADIGE River are somewhat larger than for the outlet releases from

*/Plate 8d

S. VALENTINO Dam (R-22) (designated as Flood No. 3). This is due to the shorter distance of travel, the larger outlet discharge capacity and larger volume of flow involved in Flood No. 4. The flows of the latter flood slightly exceed bankfull conditions, while Flood No. 3 would be at or slightly below banks. Critical effects at selected key stations along the ADIGE River for Flood No. 4 extracted from the summary of effects in Table 6 are presented in the following tabulation:

PEAK VALUES - FLOOD NO. 4

Station No.	Stream Depth	Overflow Height	Width Flooded	Mean Surface Vel.	Duration above bank
G-31	5.0	1.0	0.4	1.0	2.5
G-33	4.0	Bankfull	0.3	1.4	0
G-34	3.5	0.5	0.9	0.7	3.0

4-04 MAJOR FLOOD WAVES

a. General. In this paragraph are contained discussions of the major artificial flood waves that could be produced along the TAGLIAMENTO, PIAVE and ADIGE Rivers by breaching of the LUMIEI (R-4), PIEVE DI CADORE (R-11), S. VALENTINO (R-22), and S. GIUSTINA (R-28) Dams. As discussed in paragraph 4-03a, the flood waves resulting from breaching of those dams would be more critical than those from the smaller reservoirs listed in Table 4. A comprehensive study of artificial flood waves that could be produced from all the dams within the region would involve considerable additional engineering data and consume much more time than was available for this report. Reference is made to paragraph 2-10 and to Exhibit A for description of the dams studied, to Plate 1 for locations, to Plates 8a through 8d for sketches of the structures, and to Table 4 for summary of dam data.

b. Hydrologic considerations.

(1) Reference is made to paragraph 4-03b for discussion of the influence of initial stream flow, initial reservoir stage and storage, flood wave volume losses upon artificial flood effects and for discussion of the values of those factors assumed for purposes of this study.

c. Means of creating major flood waves.

(1) General. Breaching of the dams considered would produce major flood waves of appreciable magnitude but of short duration in the stream valleys downstream of the breached dams. The type, shape and size of breaches assumed for each structure are hypothetical but were selected to approximate the largest feasible effective breach openings believed likely to be produced in those dams by bombing or by placed

demolition charges. In this connection, it should be noted that the influence of channel characteristics and volume of released water upon flood wave magnitude and duration becomes progressively more critical than the shape or size of the breach as the flood wave travels farther downstream from the breached dam. The nature and size of assumed breaches are discussed in following paragraphs. For purposes of identification and classification, the essential elements of the breaches are designated as follows:

Type of Breach	Shape	Max. Depth (m)	Top Width (m)	Dam
A	Parabolic	23	68	LUMIEI PIEVE DI CADORE S. GIUSTINA
B-1	Circular	(30 m diameter)		LUMIEI
B-2	Circular	(25 m diameter)		S. GIUSTINA
C	Eroded Parabolic	20	64	S. VALENTINO

(2) Type A Breach.

(a) The bombing of the MOHNE, SORPE, and EDER DAMS in Germany by the RAF in May 1943 (described in Ref. 85) provided the basis for estimating the size and shape of this type of breach. Inasmuch as the LUMIEI, PIEVE DI CADORE and S. GIUSTINA Dams are concrete arch dams, it was considered that openings similar to that produced by bombing of the EDER Dam, a stone masonry gravity structure, could be effected. Reference is made to Plates 8a, 8b and 8c for sketches of the dams considered in this phase of the study.

(b) The assumed breach approximates a parabolic shape corresponding closely to the equation:

$$x^2 = 51 y$$

where x = horizontal distance from vertical axis of the opening

y = vertical distance above lowest point of opening.

(c) In order to permit comparative evaluation of resulting artificial flood waves, it was further assumed in all cases that the lowest point of the breach openings would be 23 m below the initial reservoir water surface (similar to conditions at the EDER DAM breach). Therefore, the top width of the opening at the reservoir water surface would be about 68 m and the initial discharge would be 8500 m^3/sec. The discharge would rapidly drop with lowering of the pool stage as the water stored in the reservoir rushed out through the breach.

(3) Type B-1 Breach. Due to the great height of the LUMIEI Dam (120 m), breaching of an opening near the bottom of the dam would result in a much higher initial rate of discharge than could be caused by a breach in the top of the dam. Since this dam is a cantilever or so-called "cupola" concrete arch dam (as illustrated on Plate 8a), it was considered that it might possibly be feasible to puncture a large hole near the bottom of the dam by proper placement of demolition charges without causing complete collapse of the structure. It was arbitrarily assumed that the hole would approximate a circular opening with a radius of about the same dimension as the thickness of the dam at the point of the charge. For the LUMIEI Dam, the centerline of the circular breach opening was assumed at elevation 920 (60 m below the initial full pool water surface). The diameter of the opening was assumed as 30 m, resulting in an initial peak discharge of 14,600 m^3/sec.

(4) Type B-2 Breach. This is similar to the type B-1 breach described in the preceding subparagraph except that the diameter of the circular breach was considered to be 25 m, and the centerline located at elevation 442.5, about 87.5 m below the initial full pool of S. GIUSTINA Dam (R-28). The resulting initial peak discharge would be 12,400 m^3/sec. Reference is made to Plate 8d for sketches of the S. GIUSTINA dam structure.

(5) Type C Breach.

(a) Breaching of earth dams like the S. VALENTINO Dam (R-28) involves various special factors (see Plate 8c for sketches of this dam). It is probable that the flow of water through a small breach in the top of an earth dam would erode a progressively deeper and wider opening as indicated in Reference 85. The exact progression of this erosion effect is not readily determinable.

(b) For purposes of this study, it was assumed that an initial 5 m deep parabolic breach in the top of S. VALENTINO Dam would be enlarged by erosion to a 20 m deep parabolic breach in approximately 4.5 hours. The final assumed breach depth corresponds to about two-thirds of the total dam height. The final assumed top width of the breach opening would be about 64 m and a peak discharge of 2600 m^3/sec would be attained about 4 hours after the initial breaching. (The discharge hydrograph from S. VALENTINO Dam is shown as Artificial Flood No. 8 on Plate 13c).

d. Effects of major flood waves.

(1) General. The effects of artificial major flood waves on the TAGLIAMENTO, PIAVE and ADIGE Rivers produced by breaching of the LUMIEI (R-4), PIEVE DI CADORE (R-11), S. VALENTINO (R-22), and S. GIUSTINA (R-28) Dams are summarized in Table 7. Plates 13a through 13c show representative discharge hydrographs at key locations as well as profiles of the peak discharge. Due to the scarcity of accurate available data regarding the details of levees and other features of the flood-plains

along these streams, broad assumptions as to extent of overbank flooding had to be made. Breaching or overtopping of levees and changes or errors in assumed features of the flood-plain would greatly influence the magnitude and duration of artificial flood waves. Consequently, the effects reviewed in this study should be considered as indicative of relative flooding possibilities, rather than accepted as being precise values, due to the many complex indeterminable factors involved in the problem. The major flood waves are designated for purpose of identification as follows:

Artificial Flood No.	River Basin	Dam	Serial No.	Type of Breach (see Par. 4-04c)
5	TAGLIAMENTO	LUMIEI	R-4	A (Parabolic)
6	do	do	do	B-1 (Circular)
7	PIAVE	PIEVE DI CADORE	R-11	A (Parabolic)
8	ADIGE	S. VALENTINO	R-22	C (Eroded Parabolic)
9	do	S. GIUSTINA	R-28	A (Parabolic)
10	do	do	do	B-2 (Circular)

(2) Artificial Flood No. 5 involves the major flood wave on the TAGLIAMENTO River resulting from breaching of LUMIEI Dam (R-4) with a "Type A" parabolic breach. Reference is made to paragraph 4-04c(2) for description of this "Type A" breach and to Plate 8a for sketches of the dam structure. The initial water surface elevation in the reservoir of 980.0 m above msl was considered to be 23 m above the lowest point of the breach opening. Approximately 32.7 million m^3 of water are contained between those elevations. The initial peak discharge of 8500 m^3/sec would drop rapidly to less than 1000 m^3/sec in 2 hours as indicated on the dam discharge hydrograph on Plate 13a. The reservoir stage would be lowered to the low point of the breach opening in about 9 hours. An important characteristic of these sharp, short-duration breach discharge hydrographs is the great reduction of peak flow effected by channel turbulence and friction. As may be seen from the summary of effects in Table 7 and from the peak discharge profile of Plate 13a, the peak discharge might be expected to be reduced to 4085 m^3/sec at PIAN DEL SAC (G-7), located 9 km below LUMIEI Dam. This corresponds to approximately 50 percent reduction of peak. The peak discharge at PASSO CANUSSIO (G-11) 88 km below the dam would be only 1300 m^3/sec, representing an increase in discharge of 1180 m^3/sec, and in stage of 3.0 m above initial base flow conditions at that place. The duration of flooding above banks would be only about one-half* along most of the river downstream of the dam. Reference is made to the artificial flood graphs on Plate 13a and to the summary of effects in Table 7. Representative critical effects at key locations extracted from Table 7 are presented in the following tabulation:

*/day

PEAK VALUES - FLOOD NO. 5

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above bank days
G-8	4.0	2.5	1.0	1.6	0.25
G-10	5.5	0.5	0.4	1.9	0.5
G-11	5.0	1.5	1.5	1.7	0.5

(3) Artificial Flood No. 6. This represents the major flood wave on the TAGLIAMENTO River created by breaching a "Type B-1" circular opening in the lower part of LUMIEI Dam (R-4). Plate 8a shows sketches of the dam and paragraph 4-04c(3) includes a description of this breach. As may be seen by the summary of effects in Table 7 and the artificial flood graphs of Plate 8a, the magnitude and duration of the results would be appreciably larger than for the "Type A" parabolic breach of the top of the dam designated as Flood No. 5 and discussed in the preceding paragraph 4-04d(2). This is largely due to the higher initial peak discharge and the larger volume of water discharged through the lower-located breach opening of Flood No. 6 (69.4 million m^3 contrasted to 32.7 million m^3 for Flood No. 5). The initial peak discharge of 14,600 m^3/sec of Flood No. 6 would drop to less than 1000 m^3/sec in about 2.5 hours. The reservoir stage would be lowered to the elevation of the bottom of the breach opening in about 7 hours. The peak discharge would be drastically reduced as the wave traveled downstream, being 10,105 m^3/sec at G-7, 9 km below the dam, and 3630 m^3/sec at PASSO CANUSSIO (G-11), 88 km below the dam. This corresponds to an increase of 3510 m^3/sec in discharge or 2.0 m increase in stage above assumed base flow conditions at the latter location, compared to equivalent values of 1180 m^3/sec and 1.5 m for Flood No. 5. The summary in Table 7 and the flood graphs of Plate 13a illustrate the effects of artificial flood waves along the TAGLIAMENTO River below LUMIEI Dam. A significant feature is the short duration of overbank flooding, i.e. less than one-half day. Extracts from Table 7 of critical effects of Flood No. 6 at key locations follow:

PEAK VALUES - FLOOD NO. 6

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above bank days
G-8	6.0	4.5	1.5	2.3	0.25
G-10	7.5	2.5	0.7	2.8	0.5
G-11	5.5	2.0	2.5	1.8	0.5

(4) Artificial Flood No. 7 concerns the PIAVE River. It is the flood wave produced by breaching a "Type A" parabolic opening in the top of the PIEVE DI CADORE Dam (R-11) under full pool conditions. See Plate 8b for sketches of the dam and paragraph 4-04c(2) for description of the assumed breach. The initial peak discharge of 8500 m^3/sec would drop sharply to less than 1000 m^3/sec in about 3 hours and slowly drop to zero flow within 4 days as the remainder of the 43.6 million m^3 of water contained in the reservoir above the elevation of the breach would be discharged through the breach opening. During passage of the flood wave downstream, the peak discharge would be considerably reduced, i.e. to 3580 m^3/sec near PERAROLO, 5 km below the dam, and to 1050 m^3/sec at PONTE DI PIAVE (G-21), 135 km downstream from the dam. The peak discharge at the latter station (G-21), represents an increase of only 930 m^3/sec above the initial base flow. This is but 11 percent of the original peak discharge at the dam. On Plate 13b are shown the artificial flood graphs illustrating the reduction in peak discharge and the change in shape of the flood wave. Effects are summarized in Table 7. As noted in paragraph A-06h of Exhibit A, facilities exist near the SOVERZENE Weir (R-14) for diversion of water for power purposes to the MESCHIO River, a tributary of the LIVENZA River. However, insufficient data were available to permit analysis of the effects of diversion of the artificial flood wave to the LIVENZA River. Breaching of levees in the lower reaches of the PIAVE River would disperse the flow over a wide area. This is especially significant in the lower reaches below the gaging station G-21, where the raised banks of the river lie as much as 6 m above the level of the plain. Detailed field reconnaissance would be required to evaluate this possibility. Critical effects at selected key stations are presented in the following tabulation to illustrate the features of this artificial flood wave:

PEAK VALUES - FLOOD NO. 7

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above bank days
BELLUNO	9.5	6.5	0.4	1.8	1.0
G-20	3.0	1.0	0.9	1.2	1.0
G-21	4.0*	1.5*	1.5*	0.8	1.0

*Assuming major levees intact and not overtopped.

(5) Artificial Flood No. 8 covers the major flood wave produced on the ADIGE River by breaching S. VALENTINO Dam (R-22). The assumed breach in the top of this earth dam is the "Type C" eroded parabolic breach described in paragraph 4-04c(5). Plate 8c contains sketches of this dam. Progressive erosion of the opening would result in a peak discharge of 2600 m^3/sec that would occur about 4 hours after the initial breaching as shown by the breach discharge hydrograph on Plate 13c.

Approximately 84 million m^3 of the total 110 million m^3 total storage capacity of the reservoir would be discharged through the breach opening in nearly 4 days. The resulting flood wave becomes quite flat-crested as the wave travels downstream, as evidenced by the discharge hydrographs shown on Plate 13c. At the junction of the NOCE and ADIGE Rivers, 132 km below S. VALENTINO Dam, the peak discharge would be 960 m^3/sec, representing an increase of 740 m^3/sec above initial base flow. At ALBEREDO D'ADIGE (G-34), located in the coastal plain region 285 km downstream from the dam, the resulting peak discharge of 710 m^3/sec represents an increase above base flow condition of 460 m^3/sec discharge or 1.0 m increase of river stage. Reference is made to the artificial flood graphs on Plate 13c and to the summary of effects in Table 7 for data on the magnitude and duration of the flood wave. A tabulation of critical effects at selected key stations follows to illustrate representative effects:

PEAK VALUES - FLOOD NO. 8

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above bank days
G-28	8.5	1.5	1.3	1.2	1.5
G-31	5.5	1.5	0.5	1.0	1.5
G-33	4.0	Bankfull	0.3	1.4	0
G-34	3.5	0.5	1.2	0.7	1.5

(6) Artificial Flood No. 9 would result from a "Type A" parabolic breach in the top of S. GIUSTINA Dam (R-28). (See paragraph 4-04c(2) for description of the breach and Plate 8d for sketches of the dam). The nature of the resulting flood wave on the ADIGE River is illustrated by the artificial flood graphs of Plate 13c; its effects are summarized in Table 7. A peak flow of 8500 m^3/sec would be discharged from the breach, dropping rather sharply to less than 1000 m^3/sec in 5 hours. Discharge through the breach would then drop more slowly, as the reservoir water surface receded to the elevation of the low point of the breach opening. This would take about 8 days. Approximately 74 million m^3 of the 182.2 million m^3 total reservoir storage would pass through the breach. At the junction of the NOCE and ADIGE Rivers, 27 km below S. GIUSTINA Dam, the peak discharge would be 5350 m^3/sec above the initial base flow of 200 m^3/sec at that location. Further downstream at AIBEREDO D'ADIGE (G-34), located on the ADIGE River 180 km downstream from the dam, the peak flow would be 1500 m^3/sec. This is 1250 m^3/sec above base flow and corresponds to an increase in stage of 1.5 m, assuming that the levees are intact and not overtopped by the flood wave. Reference is made to the artificial flood graphs of Plate 13c and to the summarized effects listed in Table 7 for additional data on the nature of the flood wave. Representative critical effects at selected key locations appear in the following tabulation:

PEAK VALUES - FLOOD NO. 9

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above banks days
G-31	8.5	4.5	0.8	1.2	1.0
G-33	5.5	1.5	0.4	1.5	1.0
G-34	4.0*	1.0*	2.0*	0.8	1.0

*Assuming major levees intact and not overtopped.

(7) Artificial Flood No. 10 likewise represents a flood wave on the ADIGE River produced by breaching of S. GIUSTINA Dam (R-28). In this case, a "Type B-2" circular breach in the lower part of the dam is involved, as described in paragraph 4-04c(4). The initial peak discharge of 12,400 m^3/sec may be compared with a peak of 8500 m^3/sec resulting from a "Type A" parabolic breach of the top of this dam as involved in Flood No. 9 and described in the preceding sub-paragraph. The volume of water discharged through the "Type B-2" breach of Flood No. 10 is also much larger than through the "Type A" breach of Flood No. 9, being about 180 million m^3 in 9 hours of the total 182.2 million m^3 capacity of the reservoir compared to the 74 million m^3 in 8 days involved in Flood No. 9. These factors are the primary reason for the "block-like" shape of the Flood No. 10 discharge hydrograph shown on Plate 13d, as contrasted to the "triangular" shape of the Flood No. 9 hydrograph. As the wave travels downstream, the peak discharge of Flood No. 10 would be lowered to 8520 m^3/sec, an increase of 8320 m^3/sec above base flow at the junction of the NOCE and ADIGE Rivers, 27 km below the S. GIUSTINA Dam. Channel and flood-plain storage and frictional forces would reduce the peak discharge at ALBEREDO D'ADIGE to 3160 m^3/sec, an increase in discharge of 2910 m^3/sec above base flow at that location. This would correspond to raising the stage 2.0 m above the assumed base flow conditions, considering that major levees were intact and not overtopped by the flood wave. Dispersion of flow through the levee openings or into irrigation and drainage channels would considerably reduce the magnitude of the wave and its attendant flooding effects. The appreciable magnitude of this flood wave contrasted with Flood No. 9, as illustrated by the Plate 13c flood graphs, emphasizes the important influence of greater volume of flow upon the flood waves. The relatively shorter duration of flooding reflects the faster discharge rate of the Flood No. 10 breach. Effects are summarized in Table 7, and extracted critical values at key locations are shown in the following tabulation:

4-04d

PEAK VALUES - FLOOD NO. 10

Station No.	Stream Depth m	Overflow Height m	Width Flooded km	Mean Surf. Vel. m/sec	Duration above banks days
G-31	10.0	6.0	1.0	1.3	0.5
G-33	8.0	4.0	0.6	1.7	1.0
G-34	4.5*	1.5*	2.5*	0.9	1.5

*Assuming major levees intact and not overtopped

4-05 ARTIFICIAL FLOODING POTENTIALITIES OF CANALS AND LAKES

a. Canals. Breaching of levees and manipulation or destruction of control gates and pumps along the extensive irrigation and drainage canal systems of the region, described in paragraphs 2-08 and 2-12 and in Reference 4, could create "drainage obstacles" of considerable extent. Reference is made to the map showing irrigated and drainage areas of the region presented as Plate 9. Insufficient data were available to permit a detailed quantitative evaluation of these possibilities for artificial inundation. However, such operations combined with diversion of water from the headwater power reservoirs of the region, listed in Table 4 and indicated on Plate 1, and with temporary damming operations for stillwater barriers could probably permit water to be dispersed through the irrigation and drainage canals to create shallow inundation over much of the irrigated and reclaimed land shown on Plate 9. Reference is made to paragraph 4-02 and to Reference 9 for additional discussion of these artificial flooding potentialities.

b. Lakes. Insufficient data were available to permit study of the possibilities of withdrawal of the immense volume of water stored in LAKE GARDA and other lakes mentioned in paragraphs 2-13, to increase artificial flooding along the ADIGE and other rivers of the region. It is considered that such operations would be impracticable except by means of a tremendous outlay of effort and time in view of the topographic features of the region.

4-06 SUMMARY

a. General. The hydraulic features associated with artificial flooding of the streams of the region covered by this report described in preceding paragraphs 4-01 through 4-05 are herein summarized. Reference should be made to Section V of this report for discussion of associated influence upon military operations.

(1) Still-water barriers and drainage obstacles. By erection of temporary dams at bridge openings or at other constricted stream sections, still-water barriers can be created. Formation of a continuous effective water obstacle by this means is practicable only along the ADIGE River. Due to the nature of the terrain, still-water barriers would tend to be of short length along the stream but would spread out transversely over the adjacent land. Breaching of levees would extend the resulting flooded area in some cases. In others, levee breaching would result in dispersion of water to other streams or channels and thus reduce the effectiveness of the still-water barrier. In the coastal delta regions, breaching of dikes would cause water from the streams to inundate considerable areas. Reference is made to the study listed as Reference 9 for valuable detailed discussion of this possibility. Disruption of drainage and irrigation facilities would create drainage obstacles by causing shallow inundation in the reclaimed regions shown on Plate 9. The highly permeable nature of the stream bed and banks, especially in the regions lying at the foot of the mountains, might make it difficult to retain water behind temporary dams. Water released from the storage reservoirs could supplement natural flow to fill the still-water barriers. Reference is made to Plate 11 and Table 5 for locations and extent, and to paragraph 4-02 for discussion of effects of still-water barriers at specific sites. Subsequent paragraphs contain summary of results to be expected in specific river basins.

(2) Destruction of Temporary Dams. Demolition or failure of the temporary dams used for still-water barriers discussed in paragraphs 4-02 and 4-06a(1) would produce flood waves of short duration and magnitude. Significant effects would not be produced except in the reaches located within several kilometers below the destroyed barrier. Failure of such temporary dams might be caused by flow overtopping the structure. Therefore, adequate relief spillways or outlets should be provided.

(3) Stream Flow Variations. Sudden opening of the gated outlets and spillways of the large power reservoirs in the region would create detrimental flow variations along the rivers downstream of the dams. Magnitude and duration would depend upon volume of water released from the reservoir, rate and duration of discharge through the outlets, location of dam along the stream, hydraulic stream characteristics, height and nature of banks, flood-plain and levees, etc. Reference is made to Plate 1 for locations of dams, to Table 4 for summary of dam data and to paragraph 2-10 and to Exhibit A for description of the existing and proposed hydroelectric power developments. Release of water from the larger reservoirs affords the greatest potential effects. Significant results might be attained by proper synchronized combination of releases from several reservoirs. However, insufficient data and time were available to permit such studies. Reference is made to paragraph 4-03 for detailed discussion of the effects of flow variations from four of the largest reservoirs in the area to illustrate the relative potentialities.

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Effects are summarized in later paragraphs for specific river basins.

(4) Major Flood Waves. Breaching of the dam structures of the many hydroelectric power projects located in the mountain and "high terrace" zones of the region would create major flood waves of appreciable magnitude but short duration. The height as well as the length of a flood wave depends largely upon the volume of water released through the breach opening. Therefore, in general it might be stated that breaching of dams having large reservoir storage capacity would be most productive. Also, breaches or holes in the structure extending closer to the bottom of a dam would release a greater portion of the reservoir storage and consequently produce more significant results than shallower breaches near the top of a dam. Reference is made to Plate 1 for dam locations, to Table 4 for summary of dam data, to Plates 8a through 8d for sketches of typical dams, and to paragraph 2-10 and Exhibit 1 for description of existing and proposed hydroelectric power dams and projects. Due to limitations imposed by data available and time allotted for this study, detailed analysis was made of the effect of breaching of dams of the largest reservoirs in each major stream basin. Breaching of those dams probably would produce most significant results and are representative of maximum expected effects. In order to produce significant flood waves by breaching of the dams of the other smaller reservoirs, coordinated breaching of several dams would be advisable. Discussion of the effects of major flood waves produced by breaching of the four large dams selected for detailed analysis is contained in paragraph 4-04. The flooding potentialities of major artificial flood waves for individual streams are summarized in subsequent paragraphs.

(5) Canals. Breaching of dikes and manipulation of control gates and pumps along the extensive irrigation and drainage canal system could cause shallow inundation of surrounding terrain. Possible ultimate extent could spread over the areas shown on Plate 9 if sufficient water were available during the rainy season or as supplied from the hydroelectric reservoirs. Reference is made to paragraphs 4-02 and 4-05a and to References 4 and 9 for additional discussion.

(6) Coastal Delta Region. Deliberate inundation of the regions in the vicinity of the coastal deltas of the rivers in this area would be possible. The stream embankments in that region lie close to the river and river stages exceed the elevation of surrounding land during high water periods. Breaching of those dikes combined with natural high water conditions or artificial flow variations or flood waves from the hydroelectric reservoirs would induce shallow flooding of considerable extent near the mouths of the streams along the ADRIATIC SEA. Reference is made to paragraphs 4-02 and 4-06a(1) and to References 4 and 9 for additional discussion.

(7) Variation in base flow conditions. The effects of artificial flood waves or flow variations depend largely upon the base flow (i.e. the flow in the stream before arrival of the flood). The studies presented in this report were based upon an assumed base flow approximating mean water conditions. The following tabulation illustrates the method that could be employed to estimate the comparative effects produced by base flow conditions other than those used in this report.

FLOOD NO. 1 - TAGLIAMENTO RIVER AT PASSO CANUSSIO (G-11)

Item	Unit	MW Conditions	HW Conditions	Source
(1) Base flow	m^3/sec	120	400	Given
(2) Discharge increase	"	450	450	Table 6
(3) Crest discharge	"	570	850	(2) plus (3)
(4) Initial gage height	m	2.0	3.5	Plate 7a for (1)
(5) Crest gage height	"	4.0	4.5	Plate 7a for (3)
(6) Stage increase	"	2.0	1.0	(5) minus (4)
(7) Initial mean surface velocity	m/sec	0.7	1.4	Plate 7a for (4)
(8) Crest mean surface velocity	"	1.5	1.6	Plate 7a for (5)
(9) Velocity increase	"	0.8	0.2	(8) minus (7)

b. ISONZO River.

(1) Still-water barriers and drainage obstacles. Temporary damming of the stream at bridges or other constricted sections, like Site No. 1 shown on Plate 11 and in Table 5, would create short still-water barriers of about 0.5 km length and 0.75 km width and averaging about 1 m deep. Associated breaching of levees would be necessary. Drainage obstacles could be created by disruption of irrigation and drainage facilities in the reclaimed area on the left bank below GRADISCA, shown on Plate 9. Reference is made to paragraph 4-02d(2) for more detailed discussion.

(2) Stream flow variations. Releases of water from the outlets of the three small reservoirs designated as R-1, R-2 and R-3 on Plate 1 and in Table 4 would probably not produce significant flooding (unless combined with the creation of still-water barriers and levee breaching operations) due to the small volume of water that could be released. Detailed study and additional data would be required to verify this estimate.

(3) Major flood waves. The small storage capacity of the three dams in the basin (see R-1, R-2 and R-3 on Plate 1 and in Table 4), limit the artificial flooding potentialities. Breaching of the dams would produce short flood waves. Significant increases in stream velocity and in depth and width of flooding would probably be confined to the upper reaches close to the breached dams.

c. TAGLIAMENTO River.

(1) Still-water barriers and drainage obstacles. Breaching of levees along the delta sections of the lower 40 km could inundate areas up to 6 km on each side during moderate to high stages. However, suitable sites for temporary dams are lacking in those reaches. Erection of temporary dams in the reach from 40 to 90 km above the mouth would flood the one-kilometer wide braided stream bed to an average 1 m depth for a distance of about 1 km upstream, similar to the results at Site No. 3 shown in Table 5 and on Plate 11. Breaching of levees would increase the inundated area. Some flooding may be induced in the reclaimed areas on the left bank shown on Plate 9 by manipulation of the irrigation and drainage facilities of that section. Paragraph 4-02d(3) contains additional discussion.

(2) Stream flow variations. Some flooding to cover the mud and samd flats in the wide braided stream bed of this river could be produced by regulated releases from the LUMIEI Dam, located on a headwater tributary of the TAGLIAMENTO River. Reference is made to paragraph 4-03d(2) for detailed discussion of this possibility, to Plate 13a for resulting artificial flood hydrographs and to Table 6 for summary of effects of this flow variation designated therein as Artificial Flood No. 1. Refilling of the reservoir would require considerable time except during periods of intense runoff as indicated in paragraph 4-03b(3). Therefore, cyclic effects could be produced only by limiting the duration of releases so as not to deplete the reservoir storage. Representative effects of Artificial Flood No. 1,' produced by sustained releases from the outlets of LUMIEI Dam, are presented in the following tabulation:

Item	Unit	PONTE DI PINZANA G-10 (Km 89)	PASSO CANUSSIO G-11 (Km 45)
Amplitude of rise	m	1.5	2.0
Rate of rise	m/hr	0.1	0.1
Time of crest	hr	24	34
Overflow height	m	Bankfull	0.5
Width flooded	km	0.2	0.4
Mean surface vel. at crest	m/sec	1.2	1.5

(3) Major flood waves. Although at present only one major dam is located within this basin (i.e. the LUMIEI Dam, R-4), its great height and large reservoir storage capacity affords excellent opportunity for creation of significant flood waves by breaching of that structure. Reference is made to paragraph 4-04d(2) and (3) for detailed discussions, to Plate 13a for artificial flood graphs and to Table 7 for summarized effects of Artificial Floods Nos. 5 and 6, produced by breaching of that dam. While the duration would be short, the velocity of flow and the rate of change of stage would be appreciable. During passage of the flood peak, fairly wide areas could be flooded along the lower reaches of the river. The following tabulation shows representative effects of these flood waves (Artificial Floods Nos. 5 and 6) produced by breaching LUMIEI Dam:

		PONTE DI PINZANO G-10 (Km 89)		PASSO CANUSSIO G-11 (Km 45)	
Item	Unit	Flood 5	Flood 6	Flood 5	Flood 6
Amplitude of rise	m	3.5	5.5	3.0	3.5
Rate of rise	m/hr	1.8	1.8	1.0	0.7
Time of crest	hr	5	6	10	12
Overflow height	m	0.5	2.5	1.5	2.0
Width flooded	km	0.4	0.7	1.5	2.5
Mean surface vel. at crest	m/sec	1.9	2.8	1.7	1.8

d. LIVENZA River.

(1) Still-water barriers and drainage obstacles. Interference with drainage facilities and breaching of levees could cause shallow inundation of considerable extent in the reclaimed land shown on Plate 9 located on the left bank along the lower 34 km. Still-water barriers averaging about 1 km long by 1 km wide and 0.75 m deep might be created in the river valley by combination of levee breaching and temporary damming operations in the vicinity of Site No. 5 (Km 45) as indicated in Table 5 and on Plate 11. Reference is made to paragraph 4-02d(4) for more detailed discussion.

(2) Stream-flow variations. Releases of water from the outlets of the three dams located on the RAI-MESCHIO tributary of the LIVENZA River and designated as R-6, R-7 and R-8 on Plate 1 and in Table 4 would probably produce shallow flooding of the wide braided stream bed along the lower reaches. In addition, there are existing facilities permitting diversion of flow from the upper PIAVE River into the LIVENZA watershed near SOVERZENE (R-14). Insufficient data were available to verify these conclusions.

(3) Major flood waves. Breaching of the LAGO S. CROCE earth dam (R-6), which has a 120 million m^3 reservoir, coupled with destruction or breaching of the two smaller downstream dams (designated as R-7 and R-8 on Plates 1 and 3c and in Table 4) would probably produce major flood waves of considerable effectiveness on the LIVENZA River. However, insufficiency of available data precluded quantitative analysis in this report.

e. PIAVE River.

(1) Still-water barriers and drainage obstacles. Inundation of the extensive irrigated and reclaimed areas on both sides of the PIAVE River shown on Plate 9 might be effected by manipulation of drainage and irrigation facilities. Breaching of levees could be quite effective as the river lies higher than the surrounding land along the lower reaches. Still-water barriers in the reach between Site No. 6 (Km 23) and Site No. 8 (Km 60), shown on Plate 11 and listed in Table 5, could flood the one-kilometer area between the embankments to average depths of less than1.5 m and lengths of about 1 km. Breaching of levees would tend to disperse the flooding transversely, as discussed in paragraph 4-02d(5).

(2) Stream flow variations. The headwaters of this river contain a number of reservoirs designated as R-9 to R-16, inclusive, on Plate 1 and Table 4. Releases from the outlets of these dams could be expected to produce flooding of the 0.5-2 kilometer wide flat alluvial meander zone along the lower reaches of the PIAVE River. Associated breaching of embankments and levees in the coastal zone could inundate the surrounding area which generally lies at a lower elevation than the stream bed. As noted in paragraph A-06h of Exhibit A, flow can be diverted into the LIVENZA River basin near SOVERZENE (R-14). With the exception of PIEVE DI CADORE Dam, (R-11), most of the reservoirs are small and combined synchronized releases would be necessary to produce significant flow variations along the PIAVE River. Analysis of potential effects was confined to the large PIEVE DI CADORE Dam outlet releases. Reference is made to paragraph 4-03d(3) for detailed discussion, to Plate 13b for resulting artificial flood graphs and to Table 6 for summary effects of this flow variation designated therein as Artificial Flood No. 2. Cyclic effects of lesser magnitude and duration could be achieved by limiting the duration of releases from the outlets so as not to unduly deplete the storage in the reservoir. Refilling of the reservoir would take a long time except during the seasons of high runoff, as indicated in paragraph 403b(3). The following tabulation lists representative effects of Artificial Flood No. 2 illustrating the potential effects of flow variations along the PIAVE River:

Item	Unit	SEGUSINO G-19 (Km 95)	PONTE DI PIAVE G-21 (Km 42.5)
Amplitude of rise	m	1.5	1.0
Rate of rise	m/hr	0.05	0.03
Time of crest	hr	32	53
Overflow height	m	0.5	0.5
Width flooded	km	0.2	1.5
Mean surface vel. at crest	m/sec	1.3	0.7

(3) Major flood waves. An appreciable flood wave would result from breaching of the PIEVE DI CADORE DAM (R-11). Breaching of the several other dams now existing in the basin (designated as R-9, R-10, and R-12 to R-16, inclusive, on Plates 1 and 3d and in Table 4) would also produce flood waves. However, due to their small reservoir storage capacities, the effects would not be significant except for short distances below the breached dams unless the waves could be combined. Construction of additional proposed reservoirs might increase the artificial flood wave possibilities. Analysis was made of the effects produced by breaching of PIEVE DI CADORE Dam to illustrate the possible effectiveness of major artificial flood waves in this basin. (See paragraph 4-04d(4) for discussion, Plate 13b for flood graphs, and Table 4 for summary of effects of Artificial Flood No. 7, produced by breaching the PIEVE DI CADORE Dam). Appreciable flooding, especially in the lower reaches, could be achieved for short periods. Also, as noted in paragraph A-06h of Exhibit A, flow could probably be diverted into the LIVENZA River basin by proper operation of the SOVERZENE Weir (R-14). However, insufficient data were available to permit study of that feature. Breaks or overtopping of levees in the lower reaches would divert a considerable volume of the flow to flood extensive areas but would thus considerably reduce the effects at locations downstream from the levee breach. Representative effects are summarized below for Artificial Flood No. 7:

Item	Unit	SEGUSINO G-19 (Km 95)	PONTE DI PIAVE G-21 (Km 42.5)
Amplitude of rise	m	3.0	1.5*
Rate of rise	m/hr	0.3	0.1
Time of crest	hr	14	26
Overflow height	m	2.5	1.5*
Width flooded	km	0.3	1.5*
Mean surface vel. at crest	m/sec	1.9	0.8

*Assuming major levees intact and not overtopped.

f. BRENTA River.

(1) Still-water barriers and drainage obstacles. The entrenched nature of the stream-bed minimizes the possibility of creating effective water obstacles by means of erection of temporary dams as discussed in paragraph 4-02d(6). However, the many irrigation and drainage canals in the large reclaimed areas adjacent to this stream as indicated on Plate 9, offer opportunity of creation of extensive drainage obstacles by breaching of canal dikes and disruption of other drainage and irrigation facilities.

(2) Stream flow variations. Since this river basin has only one existing reservoir, a small one designated as R-17 on Plate 1 and in Table 4, the possibility of producing detrimental flow variations along this stream are insignificant.

(3) Major flood waves. The present lack of large reservoirs in this basin minimizes the possibilities of producing major artificial flood waves.

g. ADIGE River.

(1) Still-water barriers and drainage obstacles. The ADIGE River affords good possibilities for formation of a continuous water obstacle. Breaching of the river levees would flood large areas on both sides of the stream, as the water surface lies higher than the general terrain except during periods of low stages. A considerable volume of water is available in the many hydroelectric reservoirs in the area to supplement natural flow. Reference is made to Table 5, Plate 11, and paragraph 4-02d(7) for additional information. References 4 and 9 also contain discussion of potential inundation including possible locations for deliberate dike breaches to produce maximum effect.

(2) Stream flow variations.

(a) The large number of existing dams and reservoirs in this river basin (Serial No. R-18 to R-37, inclusive, on Plate 1 and Table 4) afford many opportunities of creating ~~detrimental~~ flow variations along the ADIGE River. It was not practical to study the effects of all of these within the limits of available data and time allotted to the study. Consequently, analysis was made of the effects of releases from the outlets of the two largest reservoirs within the area, namely S. VALENTINO (R-22) and S. GIUSTINA (R-28). It is believed that the results of this study indicate the relative potentialities within the basin. Releases of water from the outlets of the dams could produce shallow flooding covering about a 1-kilometer wide strip in the immediate vicinity of the streams. Flow variations coupled with breaching

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of levees and manipulations of drainage and irrigation facilities in the low plains and coastal region below VERONA could inundate a considerable area limited by the volume of water available for release from the reservoirs. Reference is made to paragraphs 4-03d(4) and (5) for discussions of the flow variations produced by releases from S. VALENTINO Dam (R-22) and S. GIUSTINA Dam (R-28), designated as Artificial Floods Nos. 3 and 4, respectively. Artificial flood graphs are shown on Plate 13c and the effects are summarized in Table 6. Comparative results of both artificial flood waves are shown in the following tabulation:

Item	Unit	PESCATINA G-33 (Km 168) Flood 3	Flood 4	ALBEREDO D'ADIGE G-34 (Km 114) Flood 3	Flood 4
Amplitude of rise	m	0.5	1.5	0.5	1.0
Rate of rise	m/hr	0.01	0.05	0.01	0.02
Time of crest	hr	90	52	113	79
Overflow height	m	In banks	Bankfull	Bankfull	0.5
Width flooded	km	0.2	0.3	0.6	0.9
Mean surface velocity at crest	m/sec	1.3	1.4	0.7	0.7

b. Coordinating releases from the two dams by lagging the opening of S. GIUSTINA Dam (R-22) 36 to 48 hours after opening of S. VALENTINO Dam (R-28) to synchronize the flows would produce slightly higher peak values in the lower reaches of the ADIGE River. The resulting velocity would not be appreciably greater but some increase above the peak stage and the width and height of overbank flooding of Flood No. 4 could be expected as indicated by the following tabulation:

Item	Unit	PESCATINA G-33 (Km 168) Flood 4	Combined Floods 3 & 4	ALBEREDO D'ADIGE G-34 (Km 114) Flood 4	Combined Floods 3 & 4
Amplitude of rise	m	1.5	1.9	1.0	1.2
Rate of rise	m/hr	0.05	0.06	0.02	0.03
Time of crest	hr	52	90*	79	113*
Overflow height	m	Bankfull	0.5	0.5	0.7
Width flooded	km	0.3	0.35	0.9	1.4
Mean surface velocity at crest	m/sec	1.4	1.4	0.7	0.7

*Time after initial release at R-22 (releases of R-28 lagged 36-48 hours after initial releases at R-22 in combined Floods 3 & 4 wave).

(3) Major Flood Waves.

(a) Many opportunities exist for creation of major artificial flood waves in this basin. Proper coordination of breaching of the numerous dams, designated as R-18 through R-37 on Plate 1 and Table 4, could produce innumerable combinations of flood waves. Considerably more time and additional data would be necessary to make a comprehensive study of all these possibilities. Breaching of the dams of the two largest reservoirs, R-22 and R-28, would produce most significant results; they were therefore analyzed in this report. Resulting flooding would cover the 1-kilometer wide strip between the major levees if levees were intact and not overtopped. Breaks or overtopping of levees would reduce farther downstream effects along the river by diverting the water to inundate extensive areas in the depression lying between the ADIGE and PO Rivers. Reference is made to paragraph A-09a of Exhibit A and to Reference 9 for description of the topographic and geologic features peculiar to this basin that would influence the development and effectiveness of artificial flood waves. Detailed discussion of Artificial Floods Nos. 8, 9 and 10, the major artificial flow waves studied, is contained in paragraphs 4-04d(5) to (7), inclusive. The flood graphs shown on Plate 13c illustrate the nature of waves caused by dam breaching and Table 7 summarizes the effects along the ADIGE River. The following tabulation of effects of Artificial Floods Nos. 8, 9 and 10 illustrate the nature of major artificial flood waves produced along the lower reaches of the ADIGE River by breaching of S. VALENTINO (R-22) and S. GIUSTINA (R-28) Dams:

ALBEREDO D' ADIGE (Km 114)

Item	Unit	Breach of R-22	Breaches of R-28	
		Flood 8	Flood 9	Flood 10
Amplitude of rise	m	1.0	1.5*	2.0*
Rate of rise	m/hr	0.03	0.1	0.2
Time of crest	hr	89	42	36
Overflow height	m	0.5	1.0*	1.5*
Width flooded	km	1.2	2.0*	2.5*
Mean surface velocity at crest	m/sec	0.7	0.8	0.9

*Assuming major levees intact and not overtopped.

(b) Combined breaching of S. VALENTINO (R-22) and S. GIUSTINA (R-28) Dams would slightly increase the resulting flood wave effects below the junction of the NOCE and ADIGE Rivers. Breaching of S. GIUSTINA Dam should be delayed from 42 to 54 hours after initial breaching of S. VALENTINO Dam to secure proper synchronization of peaks below the junction of the two streams. A small increase in depth and width of flooding but a practically negligible increase in velocity would be effected as indicated by the following tabulation of comparative values at ALBEREDO D' ADIGE (G-34):

Item	Unit	Breach of R-28 Flood 10	Combined Breach of R-22 & R-29 Floods 8 plus 10
Amplitude of rise	m	2.0*	2.3*
Rate of rise	m/hr	0.2	0.2
Time of crest	hr	36	89**
Overflow height	m	1.5*	1.8*
Width flooded	km	2.5*	2.7*
Mean surface velocity at crest	m/sec	0.9	0.9

*Assuming major levees intact and not overtopped
**Time after initial breach at R-22

SECTION V
EFFECT ON MILITARY OPERATIONS

5-01 GENERAL.

The purpose of this section is to assist military planning personnel in estimating the relative value and effect of artificial floods upon associated military factors such as bridging, ferrying, and trafficability. The effects of artificial floods upon military operations may vary greatly, depending on the hydrologic and weather conditions, the tactical and logistical situation, and the type of equipment involved. Reference is made to Section IV for discussion of the hydraulic features associated with artificial flooding.

5-02 CHARACTERISTICS OF MILITARY BRIDGING.

a. The loading capacities of standard U. S. Army floating bridging under conditions classified as "Safe, Caution, and Risk Crossings," for various current velocities are tabulated in Table 8. Included are the current velocities that presumably would destroy the bridge in place with no load, the values ranging from 9 to 16 feet per second (i.e., about 2.7 to 4.9 m/sec). Table 8 is primarily based on data contained in References 87 and 88.

b. It should be noted that the velocities shown in Table 8 represent general averages. The ability of floating bridges to withstand current velocities depends upon numerous variable factors such as: special provisions for securing the bridge, the rate of change in river stage, direction and variability of current, debris carried by the stream and other considerations. Standard bridging has withstood conditions more severe than indicated in Table 8 and has failed under apparently less critical velocities.

5-03 EFFECTS OF ARTIFICIAL FLOODING DURING ACTUAL CROSSING OPERATIONS.

The artificial flooding of the PIAVE River during World War I, referred to in Paragraph 4-01e of this report, was responsible for stopping the Austrian advance at the PIAVE River according to Reference 2. The inundation prevented the Austrians from crossing the river and the complex, criss-cross pattern of irrigation canals and ditches hampered their movements. Reference 11, listed in the Bibliography, contains an evaluation of river crossings and terrain appreciation, and also notes that the German advance was stopped at the PIAVE after the CAPORETTA defeat.

5-04 EFFECT OF STILL-WATER BARRIERS AND DRAINAGE OBSTACLES.

a. Reference is made to paragraphs 4-02 and 4-06 for discussion of the hydraulic features associated with formation and augmentation of water obstacles by means of temporary damming operations or by disruption of normal drainage along the various major rivers of the VENETIAN-FRIULI PLAINS.

b. Bridging and ferrying operations within the backwater reaches upstream from the temporary dams would be hindered by reason of the resulting greater width and depth of crossing, indicated in Table 5 and on Plate 11. Approach trafficability would be reduced by the shallow overbank flooding and the increased stream depths would hinder fording at shallow spots in the affected reaches of the river. Since the resulting increased water obstacles would not be continuous along the streams (as illustrated on Plate 11), still-water barriers must be combined with other natural obstacles and with tactical operations in order to channelize military action.

c. Breaching of levees would be necessary in some cases; while in others, blocking of culverts, drainage outlets and low spots or openings in levees would be required in addition to temporary damming operations in order to create effective still-water barriers and drainage obstacles.

d. Breaching of levees along the ADIGE River during periods of moderate to high flows would create a substantial water obstacle to crossing operations and would reduce overland trafficability. A practically continuous obstacle might be so effected as indicated on Plates 10 and 11.

e. Overland trafficability in the extensive reclaimed lands shown on Plate 9 would be reduced by inundation created by disruption of drainage and irrigation facilities in those areas.

f. Overland trafficability along the coastal zone or inland from the ADRIATIC SEA would be hindered by breaching of the sea dikes or river levees in the flat low-lying tidal reaches of the streams.

g. Over much of the potentially floodable areas of the NORTH ITALIAN PLAIN, cross-country movement off the roads would be difficult or impossible even if there were no flooding because of the numerous canals which cut up the surface of the country. After flooding, the waterlogged condition of the soil over wide areas would render impossible any attempt at cross-country movement off the roads.

h. Continuous military support of the temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Destruction or failure of a temporary dam would release a flood wave of short duration that would temporarily hinder crossing operations below the structure and which might cause progressive failure of other downstream structures.

5-05 EFFECT OF FLOW VARIATIONS.

a. Reference is made to paragraphs 4-03 and 4-06 for discussion of possible detrimental flow variations that could be created on the main streams of the VENETIAN-FRIULI PLAINS region of NORTHEAST ITALY by means of regulated discharge from the major hydroelectric power dams of the area listed in Table 4 and indicated on Plate 1. Resulting flow variations analyzed in the report are summarized in Table 6 and presented graphically on Plates 13a, b and c.

b. Sudden opening of the gates of the outlets of the hydroelectric dams would produce flow variations that would hinder floating bridging or fording operations by increasing the depth and width of the streams as indicated in Table 6. The rate of change of stage would be too slow to seriously affect operations. Except in the steep reaches located in the mountainous region immediately below the dams, velocities would not be large enough to seriously hinder floating bridges or endanger fixed bridges.

c. In some cases hinderances to floating bridging or fording operations could be intensified by proper synchronization of releases from several reservoirs.

d. Cyclic variations in depth and width of streams by means of opening and closing dam outlets could increase difficulties in operation and maintenance of floating bridges. However, the duration and magnitude of the flow variation would be reduced from that effected by sustained releases.

e. The creation of still-water barriers and drainage obstacles outlined in paragraphs 4-02, 4-06 and 5-04 would be facilitated by releases of water from the reservoirs to supplement natural stream flow to provide the required volume of water.

f. No appreciable effect on bridging or crossing operations could be expected by release of water from the small power outlets of the hydroelectric dams.

g. Deliberate destruction of the structures or gates of the hydroelectric power dams in the area would prevent their use by the enemy

in producing detrimental flow variations during a later critical period and would seriously disrupt the electrical power facilities of the region. Emptying of the reservoirs would have a similar effect.

h. In order to utilize the gates of the dams in the area to produce flow variations, it would be necessary to provide for defense of the sites against enemy air or ground attacks. Breaching of the structures or damage to the operating mechanism by enemy action would prevent useful operations of the gates, especially where cyclic releases are concerned.

5-06 EFFECT OF MAJOR FLOOD WAVES.

a. Reference is made to paragraphs 4-04 and 4-06 for discussion of the hydraulic features associated with creation of major artificial flood waves on the streams of the region by breaching the dams of hydroelectric developments listed in Table 4 and indicated on Plate 1. Hydraulic effects of representative flood waves so created by breaching dams of the larger key reservoirs are summarized in Table 7 and presented graphically on Plates 13a, b and c.

b. Flood waves created by dam breaching would probably destroy or seriously damage fixed and floating bridges located short distances below the breached dams. Farther downstream, damage to fixed bridges would be problematic but floating bridging might be endangered.

c. Floating bridging operations in the steeper mountainous reaches would be hindered by the resulting high velocities of flow. In the lower reaches, velocities would probably not be sufficient to seriously damage or hinder floating bridging.

d. Stream crossings by fording, ferrying or floating bridging operations would be hindered by the appreciable magnitude and rate of rise of the artificial flood waves.

e. The duration of the flood waves would be short and consequently, any continuing interference with military operations would likewise be short.

f. The possibility of breaching of a dam could have a deterrent effect upon military operations in causing delay in stream crossing until the dam was destroyed or captured. Breaching of a dam or emptying of its reservoir would eliminate this deterrent effect.

g. Breaching of a dam would serve to reduce the time required to transfer the contents of the reservoir downstream to assist in filling of still-water barriers discussed in paragraphs 4-02, 4-06 and 5-04.

h. The electrical power supply for cities, industries and electrified railways of a large part of NORTHEAST ITALY would be seriously disrupted by breaching the numerous hydroelectric power dams in this region.

i. Breaching of levees and destruction of drainage and irrigation facilities might be necessary in some cases in order to fully exploit the maximum possible effectiveness of artificial flood waves.

j. Military support of permanent or temporary dam installations would be necessary to prevent their destruction by enemy air or ground action. Such destruction would prematurely release flood waves that could hinder action by our forces below the breached structures. Deliberate demolition of dams or barriers would prevent their use by the enemy in producing detrimental major flood waves or flow variations during a later critical period.

5-07 EFFECTS RELATED TO OTHER BASINS.

a. Artificial flooding in this region could be coordinated with similar operations on other nearby river basins to create simultaneous or progressive water obstacles affecting military actions. Specific reference is made to similar studies on the SAVA River basin of Yugoslavia and the DRAU (DRAVA) River basin of Yugoslavia and Austria, recently completed by this office and listed as References 89 and 90 in the Bibliography of this report. Additional studies are currently being made by this office on the streams of the AUSTRIAN ALPS located just north and northeast of the region covered by this report.

b. Artificial flooding measures undertaken in this region, particularly along the ADIGE River, could be coordinated with similar operations along the PO River, which closely parallels the lower ADIGE River. However, such a study was beyond the scope of this report and would involve considerable time and effort, due to the vast extent and complex nature of the PO basin.

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TABLES

TABLE I
EQUIVALENT ENGLISH-METRIC TERMS

To reduce A to B, multiply A by F. To reduce B to A, multiply B by G.

Unit A	Factor F	Factor G	Unit B
	LENGTH		
Miles	1.60935	.62137	Kilometers
Meters	3.2808	.30480	Feet
Meters	39.370	.025400	Inches
	AREA		
Square Miles	2.590	.3861	Square Kilometers
Square Miles	259.000	.0038610	Hectares
Hectares	2.47104	.40469	Acres
Acres	4046.9	.00024710	Square Meters
	VOLUME		
Cubic Meters	35.3145	.028317	Cubic Feet
Cubic Feet	28.317	.035314	Liters
Acre-feet	43560.	.000022957	Cubic Feet
Acre-feet	1233.5	.00081071	Cubic Meters
	DISCHARGE		
Cubic feet per second	1.9835	.50417	Acre-feet per 24 hours
Cubic meters per second	35.3145	.028317	Cubic-feet per second
	VELOCITY		
Miles per hour	1.60935	.62137	Kilometers per hour
Miles per hour	1.4667	.68182	Feet per second
Meters per second	3.2808	.30480	Feet per second
Meters per second	2.2369	.44704	Miles per hour
Meters per second	3.600	.2778	Kilometers per hour
Feet per second	1.097	.9113	Kilometers per hour
	WEIGHT		
Tons (metric)	1.102	.9072	Tons (short)
Tons (long)	1.016	.9842	Tons (metric)
Tons (metric)	2205.	.0004536	Pounds (avoirdupois)
Tons (metric)	1000.	.001	Kilograms
	POWER		
Horsepower (std. U.S.)	550.	.0018182	Foot-pounds per second
Horsepower (metric)	75.	.01333	Kilogram-meters per second
Horsepower (std. U.S.)	1.014	.9863	Horsepower (metric)
Kilowatts	1.3405	.7457	Horsepower (std. U.S.)
Kilowatts	1.360	.7355	Horsepower (metric)

TABLE 2

DEFINITIONS OF HYDROLOGIC TERMS

Altezza idrometrica (Gage height)	Height of water (cm) above gage zero.
Altezza della massima piena (Maximum gage height)	Highest gage height (cm) observed during operation of gaging station.
Altezza della massima magra (Minimum gage height)	Lowest gage height (cm) observed during operation of gaging station.
Media mensile dell'altezza idrometrica (Monthly mean stage)	Mean of average daily gage heights (cm) for a month averaged over a stated number of years.
Media annuo dell'altezza idrometrica (Mean annual stage)	Average of mean monthly gage heights (cm) for a year averaged over a stated number of years.
Portata giornaliera (Daily discharge)	Average rate of discharge (m^3/sec) for one day.
Portata massima giornaliera (Maximum discharge)	Maximum daily rate of discharge (m^3/sec) observed during a stated period of record.
Portata minima giornaliera (Minimum discharge)	Minimum daily rate of discharge (m^3/sec) observed during a stated period of record.
Portata media mensile (Monthly mean discharge)	Mean of average daily rate of discharge (m^3/sec) for a month averaged over a stated number of years.
Portata media annua (Mean annual discharge)	Average of mean monthly rates of discharge (m^3/sec) for a year averaged over a stated number of years.
Coefficient di deflusso (Coefficient of runoff)	Ratio of inflow to outflow for the drainage area of the gage for a stated period of time.

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TABLE 3
SUMMARY OF GAGE DATA

Station Number	River	Station Name	River km	Map Sheet (1)	Grid	Elevation Gage Zero m above msl	Year Estab-lished	Drainage Area km^2	Gage Height Maximum cm	Gage Height Maximum Date	Gage Height Minimum cm	Gage Height Minimum Date	Gage Height Mean Annual Years	Gage Height Mean Annual cm	m^3/s
G1	ISONZO	CANALE DI ISONZO	52	26III	9404	90.	1923(2)	1357	1060	11/29/23	66	10/20/29	*	*	1080
G2	ISONZO	PONTE DI SALCANO(0)	36	40AIV	9592	55.87	1926	1551	850	9/8/40	-26	3/5/32	1935-1944	73	*
G3	ISONZO	PIERIS(0)	9	40II	7874	4.	1925	3369	640	11/18/40	*	*	1937-1941	182	*
G4	CORNO	PORTO NOGARO(0)	9	40II	6175	-0.99	1919	*	328	1/20/46	-9	2/14/34	1934-1943	128	*
G5	STELLA	CASALE SACILE	20	40IV	5180	6.05	1924(3)	*	220	10/13/33	49	5/5/44	1937-1946	80	79.5
G6	STELLA	PRECENICCO(0)	9	40III	5072	-0.42	1920	*	305	10/14/33	0	2/22/32	1937-1946	92	*
G7	LUMIEI	PLAN DEL SAC	147	13II	2944	495.	1934	96	300	8/9/45	36	3/10/40	*	*	*
G8	TAGLIAMENTO	INVILLINA	130	13II	4041	345.	1932	709	284	10/5/35	6	1/17/37	*	*	155
G9	TAGLIAMENTO	PIOVERNO	109	14III	5633	224.98	1928	1990	408	11/17/40	8	1/21/41	*	*	2000
G10	TAGLIAMENTO	PONTE DI PINZANO	89	25IV	4216	160.	1923	2219	476	10/9/33	-12	1/25/37	1934-1943	72	*
G11	TAGLIAMENTO	PASSO CANUSSIO	45	40IV	4278	7.10	1925(4)	2300	530	10/29/28	50	2/9/25	*	*	*
G12	TAGLIAMENTO	FRAFOREANO	41	40III	4377	4.41	1940	2300	534	11/7/42	33	8/1/45	1940-1946	70	*
G13	TAGLIAMENTO	LATISANA(0)	32	40III	4470	0	1851	2300	970	10/20/96	-78	9/30/28	1934-1943	72	*
G14	LIVENZA	FIASCHETTI	103	39IV	0495	24.	1927	*	617	5/17/35	196	8/17/28	1937-1946	261	86.5
G15	MEDUNA	PONTE MEDUNA(0)	94	39IV	2190	14.43	1916	263	775	10/27/82	48	4/25/33	1934-1943	120	*
G16	LIVENZA	S. CASSIANO(0)	79	39IV	0883	6.07	1882	*	699	1916	6	3/18/13	1937-1946	129	*
G17	LIVENZA	MOTTA DI LIVENZA(0)	45	39III	1572	2.14	1882	*	640	11/19/35	-151	3/6/22	1937-1946	3	*
G18	PIAVE	CIMAGOGNO	192	13IV	0453	704.	1925	612	400	11/1/28	33	2/26/30	*	*	187
G19	PIAVE	SEGUSINO(0)	95	37I	2889	180.(6)	1913	3333(5)	452	10/28/28	5	2/27/33	*	*	1200

(1) AMS Map Series M791, scale 1:50,000
* Not available
(0) Influenced by tides and/or operation of navigation and diversion structures
(2) Gage ht. measurements began 1923, discharge measurements began 1925
(3) Gage ht. measurements began 1924, discharge measurements began 1925
(4) Partial record from 1925 to 1928 for discharge
(5) Diversion of flow into LAGO S. CROCE
(6) From profile

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TABLE 3
SUMMARY OF GAGE DATA

r	Map Sheet (1)	Grid	Elevation Gage Zero m above msl	Year Estab-lished	Drainage Area km^2	Gage Height						Daily Discharge					
						Maximum		Minimum		Mean Annual		Maximum		Minimum		Mean Annual	
						cm	Date	cm	Date	Years	cm	m^3/s	Date	m^3/s	Date	Years	m^3/s
	26III	9404	90.	1923(2)	1357	1060	11/29/23	66	10/20/29	*	*	1080	9/30/26	17.1	3/3/32	1926-1937	102.5
	40AIV	9592	55.87	1926	1551	850	9/8/40	-26	3/5/32	1935-1944	73	*	*	*	*	*	*
	40II	7874	4.	1925	3369	640	11/18/40	*	*	1937-1941	182	*	*	*	*	*	*
	40II	6175	-0.99	1919	*	328	1/20/46	-9	2/14/34	1934-1943	128	*	*	*	*	*	*
	40IV	5180	6.05	1924(3)	*	220	10/13/33	49	5/5/44	1937-1946	80	79.5	*	18.7	*	1937-1946	30.6
	40III	5072	-0.42	1920	*	305	10/14/33	0	2/22/32	1937-1946	92	*	*	*	*	*	*
	13II	2944	495.	1934	96	300	8/9/45	36	3/10/40	*	*	*	*	*	*	*	*
	13II	4041	345.	1932	709	284	10/5/35	6	1/17/37	*	*	155	*	4.7	*	1938-1943	19.5
	14III	5633	224.98	1928	1990	408	11/17/40	8	1/21/41	*	*	2000	11/17/40	15.4	*	1932-1943	93.0
	25IV	4216	160.	1923	2219	476	10/9/33	-12	1/25/37	1934-1943	72	*	*	*	*	*	*
	40IV	4278	7.10	1925(4)	2300	530	10/29/28	50	2/9/25	*	*	*	*	*	*	*	*
	40III	4377	4.41	1940	2300	534	11/7/42	33	8/1/45	1940-1946	70	*	*	*	*	*	*
	40III	4470	0	1851	2300	970	10/20/96	-78	9/30/28	1934-1943	72	*	*	*	*	*	*
	39IV	0495	24.	1927	*	617	5/17/35	196	8/17/28	1937-1946	261	86.5	11/18/35	6.2	*	1937-1946	14.5
	39IV	2190	14.43	1916	263	775	10/27/82	48	4/25/33	1934-1943	120	*	*	*	*	*	*
	39IV	0883	6.07	1882	*	699	1916	6	3/18/13	1937-1946	129	*	*	*	*	*	*
	39III	1572	2.14	1882	*	640	11/19/35	-151	3/6/22	1937-1946	3	*	*	*	*	*	*
	13IV	0453	704.	1925	612	400	11/1/28	33	2/26/30	*	*	187	11/1/28	7.5	2/9/25	1925-1931	21.0
	37I	2889	180.(6)	1913	3333(5)	452	10/28/28	5	2/27/33	*	*	1200	10/28/28	17.9	*	1928-1945	90.0

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Washington Dist., Corps of Engineers, June 1953

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TABLE 3
SUMMARY OF GAGE DATA

Station Number	River	Station Name	River km	Map Sheet (1)	Grid	Elevation Gage Zero m above msl	Year Estab-lished	Drainage Area km^2	Gage Height Maximum cm	Gage Height Maximum Date	Gage Height Minimum cm	Gage Height Minimum Date	Gage Height Mean Annual Years	Gage Height Mean Annual cm	Maximum m^3/s	Maximum Date
G20	PIAVE	NERVESA(0)	63.5	38II	8378	77.54	1924	3763(5)	301	10/28/38	-52	2/5/25	1937-1946	61	*	*
G21	PIAVE	PONTE DI PIAVE(0)	42.5	39III	0165	6.21	1934	3763(5)	300	11/18/40	-228	8/30/41	1935-1943	-141	*	*
G22	BRENTA	SARSON	107	37II	1174	111.55	1915	1563	465	10/28/28	-80	12/17/45	1931-1940	36	673	10/28/28
G23	BRENTA	LIMENA(0)	67	50II	2240	14.24	1876	*	645	11/17/82	-126	4/15/40	1937-1946	-10	*	*
G24	BRENTA	CORTE(0)	26.25	65IV	7121	2.08	1882	*	646	5/16/05	-90	10/26/31	1934-1943	12	*	*
G25	BACCHIGLIONE	VICENZA(0)	104	50IV	9946	27.04	1925	281	556	5/16/26	18	1843	1935-1944	60	*	*
G26	BACCHIGLIONE	MONTEGALDELLA(0)	80	50III	0935	15.06	1929	1384	768	11/18/35	-45	8/1/43	*	*	295	11/18/35
G27	BACCHIGLIONE	S. MARCO(0)	69	50II	1333	15.91	1872	1384	451	5/17/26	-321	2/25/44	1936-1945	-227	*	*
G28	ADIGE	PONTE ADIGE	312	10II	7650	238.90	1925	2642	503	11/1/26	110	5/5/38	*	*	470	2/5/35
G29	NOCE	PONTE ROVINA	319	20I	4031	772.6	1902(7)	384	280	10/4/35	11	1/31/37	*	*	72.5	6/7/37
G30	NOCE	DERMULO	294	10III	5833	365.	1923	1056	350	11/1/28	24	1/11/32	*	*	226	7/8/40
G31	ADIGE	TRENTO	253	21III	6304	186.09	1884(8)	9763	611	9/17/82	-63	4/26/96	*	*	1480	11/3/26
G32	ADIGE	SERRAVILLE	218	36III	5675	140.	1944	10514	426	6/22/46	71	4/3/44	*	*	*	*
G33	ADIGE	PESCATINA	168	48II	4538	76.2	1888(9)	10957	430	9/17/82	-244	4/30/38	*	*	1815	5/17/26
G34	ADIGE	ALBEREDO D'ADIGE	114	63I	7721	23.66	1857	11954	270	*	-365	5/5/44	1937-1946	-212	*	*
G35	ADIGE	BADIA POLESINE(0)	77	64III	9795	15.	1922	*	*	*	*	*	1936-1944	116	*	*
G36	ADIGE	BOARA PISANI	51	64II	1998	8.84	1853(10)	11954	399	11/2/28	-289	4/28/96	1932-1941	-107	1871	*
G37	ADIGE	CAVARZERRE(0)	25	65III	7002	1.98	1855	11954	555	5/18/26	-114	5/6/38	1933-1937	126	*	*
G38	ADIGE	CAVANELLA D'ADIGE(0)	10	65II	8398	1.86	1911	11954	444	9/21/37	77	5/3/38	1930-1937	201	*	*

(1) AMS Map Series M791, scale 1:50,000
* Not available
(0) Influenced by tides and/or operation of navigation and diversion structures
(5) Diversion of flow into LAGO S. CROCE
(7) Gage ht. measurements began 1902, discharge measurements began 1930
(8) Gage ht. measurements began 1884, discharge measurements began 1921
(9) Gage ht. measurements began 1888, discharge measurements began 1921
(10) Gage ht. measurements began 1853, discharge measurements began 1927

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TABLE 3
SUMMARY OF GAGE DATA

Map Sheet (1)	Grid	Elevation Gage Zero m above msl	Year Estab-lished	Drainage Area km²	Gage Height Maximum cm	Gage Height Maximum Date	Gage Height Minimum cm	Gage Height Minimum Date	Gage Height Mean Annual Years	Gage Height Mean Annual cm	Daily Discharge Maximum m³/s	Daily Discharge Maximum Date	Daily Discharge Minimum m³/s	Daily Discharge Minimum Date	Daily Discharge Mean Annual Years	Daily Discharge Mean Annual m³/s
38II	8378	77.54	1924	3763(5)	301	10/28/38	-52	2/5/25	1937-1946	61	*	*	*	*	*	*
39III	0165	6.21	1934	3763(5)	300	11/18/40	-228	8/30/41	1935-1943	-141	*	*	*	*	*	*
37II	1174	111.55	1915	1563	465	10/28/28	-80	12/17/45	1931-1940	36	673	10/28/28	14.0	2/22/22	1922-1940	71.8
50II	2240	14.24	1876	*	645	11/17/82	-126	4/15/40	1937-1946	-10	*	*	*	*	*	*
65IV	7121	2.08	1882	*	646	5/16/05	-90	10/26/31	1934-1943	12	*	*	*	*	*	*
50IV	9946	27.04	1925	281	556	5/16/26	18	1843	1935-1944	60	*	*	*	*	*	*
50III	0935	15.06	1929	1384	768	11/18/35	-45	8/1/43	*	*	295	11/18/35	5.5	8/8/43	1930-1945	29.1
50II	1333	15.91	1872	1384	451	5/17/26	-321	2/25/44	1936-1945	-227	*	*	*	*	*	*
10II	7650	238.90	1925	2642	503	11/1/26	110	5/5/38	*	*	470	2/5/35	7.8	5/7/38	1926-1943	23.5
20I	4031	772.6	1902(7)	384	280	10/4/35	11	1/31/37	*	*	72.5	6/7/37	1.7	1/21/31	1931-1939	12.5
10III	5833	365.	1923	1056	350	11/1/28	24	1/11/32	*	*	226	7/8/40	5.6	2/1/42	1929-1943	28.2
21III	6304	186.09	1884(8)	9763	611	9/17/82	-63	4/26/96	*	*	1480	11/3/26	41.0	2/8/22	1921-1942	224
36III	5675	140.	1944	10514	426	6/22/46	71	4/3/44	*	*	*	*	*	*	*	*
48II	4538	76.2	1888(9)	10957	430	9/17/82	-244	4/30/38	*	*	1815	5/17/26	49.0	2/9/22	1921-1942	252
63I	7721	23.66	1857	11954	270	*	-365	5/5/44	1937-1946	-212	*	*	*	*	*	*
64III	9795	15.	1922	*	*	*	*	*	1936-1944	116	*	*	*	*	*	*
64II	1998	8.84	1853(10)	11954	399	11/2/28	-289	4/28/96	1932-1941	-107	1871	*	58.0	*	1922-1945	251
65III	7002	1.98	1855	11954	555	5/18/26	-114	5/6/38	1933-1937	126	*	*	*	*	*	*
65II	8398	1.86	1911	11954	444	9/21/37	77	5/3/38	1930-1937	201	*	*	*	*	*	*

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Washington Dist., Corps of Engineers, June 1953

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TABLE 4
SUMMARY OF DAM DATA

No. (1)	Name of Dam	River	Basin	Map Sheet (2)	Grid Reference	Type	Drainage Area km^2	Res. Capacity $m^3 10^6$	Height m	Length m	Width (base) m	Construction Date
R1	SOTTOSELLA	ISONZO	ISONZO	26II	0110	Arch-gravity	1290	6.4	27	45	6	1939
R2	AIBA	ISONZO	ISONZO	26III	9506	Weir	-	1.3	14	52	-	1940
R3	CROSIS	TORRE	ISONZO	25I	6322	Concrete-arch	65	0.15	38	-	-	1901
R4	LUMIEI	LUMIEI	TAGLIAMENTO	13II	2546	Concrete-arch	81	72.8	136	123	14	1947
R5	ALBA	RIO ALBA	TAGLIAMENTO	14II	6243	Conc.-arch gravity	15	0.02	22	-	-	1923
R6	LAGO S. CROCE	RAI	PIAVE-LIVENZA	23II	9312	Earth	-	120.0	-	-	-	-
R7	LAGO MORTO	MESCHIO	LIVENZA	23II	9203	Earth	-	3.0	-	-	-	-
R8	LAGO RESTELLO	MESCHIO	LIVENZA	23II	9101	Gravity	-	8.0	-	-	-	-
R9	S. CATERINA	ANSIEI	PIAVE	13IV	0557	Concrete-gravity	228	6.0	44	180	40	1933
R10	COMELICO	PIAVE	PIAVE	13IV	0756	Reinforced concrete	363	1.2	45	80	8.7	1933
R11	PIEVE DI CADORE	PIAVE	PIAVE	12II	9944	Concrete-arch	-	64.3	55	300	36	1952
R12	VALLE	BOITE	PIAVE	12II	9343	Concrete-arch	-	4.2	-	-	3.5	1951
R13	VAL GALLINA	VAL GALLINA	PIAVE	23I	9321	Concrete-arch	-	5.9	86	-	15	1951
R14	SOVERZENE	PIAVE	PIAVE	23I	9120	Weir	-	-	-	-	-	1930
R15	CAPRILE	CORDEVOLE	PIAVE	12III	6947	Weir	-	-	20	-	-	1940
R16	LAGODI ALLEGHE	CORDEVOLE	PIAVE	12III	7042	Weir	-	-	16	-	-	1939
R17	PONTE DELLA SERRA	CISMON	BRENTA	22II	1301	Concrete-arch	496	0.20	35	-	-	1910
R18	PUSTERIA	RIENZA	ADIGE	4AIII	0385	Gravity	2620(4)	2.0	27	-	-	1941
R19	FORTEZZA	ISARCO	ADIGE	4AIII	0084	Concrete-arch	2620(4)	3.2	63	58	-	1941

NOTES:
(1) Serial number-See General Map, Plate 1
(2) AMS Series M791 - Scale: 1:50,000
(3) Reference Nos. in Bibliography
(4) Drainage area of BRESSANONE Power Plant
(5) Dams located on same reservoir
(6) Paragraph Reference Nos. in Exhibit A

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SECURITY INFORMATION

TABLE 4
SUMMARY OF DAM DATA

	Map Sheet (2)	Grid Reference	Type	Drainage Area km^2	Res. Capacity $m^3 10^6$	Height m	Length m	Width (base) m	Construction Date	Company	Source Reference Nos. (3)	Exhibit A Reference Nos. (5)
	26II	0110	Arch-gravity	1290	6.4	27	45	6	1939	Societa Adriatica	23, 24, 25, 26	A-04c
	26III	9506	Weir	-	1.3	14	52	-	1940	Societa Adriatica	23, 26	A-04d
	25I	6322	Concrete-arch	65	0.15	38	-	-	1901	Societa di Seta	27, 28	
MENTO	13II	2546	Concrete-arch	81	72.8	136	123	14	1947	Societa Edison	29, 37, 39	A-05c
MENTO	14II	6243	Conc.-arch gravity	15	0.02	22	-	-	1923	Societa Ermoli	27	
LIVENZA	23II	9312	Earth	-	120.0	-	-	-	-	Societa Adriatica	28, 38, 39	A-06h
A	23II	9203	Earth	—	3.0	-	-	-	-	Societa Adriatica	28, 39	A-06h
A	23II	9101	Gravity	-	8.0	-	-	-	-	Societa Adriatica	28, 39	A-06h
	13IV	0557	Concrete-gravity	228	6.0	44	180	40	1933	Societa Alto Cadore	28, 39, 40, 41	A-06c(2)
	13IV	0756	Reinforced concrete	363	1.2	45	80	8.7	1933	Societa Alto Cadore	28, 39, 40, 41, 42	A-06c(3)
	12II	9944	Concrete-arch	-	64.3	55	300	36	1952	Societa Adriatica	29, 35, 37, 39, 43, 44, 46, 80	A-06d(2)
	12II	9343	Concrete-arch	-	4.2	-	-	3.5	1951	Societa Adriatica	35, 37, 39, 43, 45, 76	A-06d(6)
	23I	9321	Concrete-arch	-	5.9	86	-	15	1951	Societa Adriatica	29, 35, 37, 39, 43, 45, 78	A-06d(4)
	23I	9120	Weir	-	-	-	-	-	1930	Societa Adriatica	29, 38, 43, 46	A-06h
	12III	6947	Weir	-	-	20	-	-	1940	Societa Adriatica	23	
	12III	7042	Weir	-	-	16	-	-	1939	Societa Adriatica	23	A-06g
	22II	1301	Concrete-arch	496	0.20	35	-	-	1910	Societa Adriatica	28	
	4AIII	0385	Gravity	2620(4)	2.0	27	-	-	1941	Montecatini Group	47, 48	A-09d(2)(c)
	4AIII	0084	Concrete-arch	2620(4)	3.2	63	58	-	1941	Montecatini Group	47, 48	A-09d(2)(b)

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SUMMARY OF DAM DATA

No. (1)	Name of Dam	River	Basin	Map Sheet (2)	Grid Reference	Type	Drainage Area km^2	Res. Capacity m^{3}10^6	Height m	Length m	Width (base) m	Construction Date	Company
R20	FUNES	ISARCO	ADIGE	11IV	9870	Weir	3045	-	-	-	-	-	Montecat
R21	PONTE ALL'ISARCO	ISARCO	ADIGE	11IV	9363	Weir	-	.24	-	-	-	-	Montecat
R22	S. VALENTINO	ADIGE	ADIGE	3III	1681	Earth	322	110.0	32	467	-	1951	Montecat
R23	VERNAGO	SENALES	ADIGE	3II	4077	Earth	-	25	40	300	-	1950	-
R24	PLIMA	PLIMA	ADIGE	9I	3656	-	1075	0.5	-	-	-	-	Societa
R25	GIOVARETTO	PLIMA	ADIGE	9I	-	Buttress	-	15	100	-	-	Under const.	Societa
R26	CARESER	NOCE	ADIGE	9III	3042	Conc.-arch gravity	14.2	16.1	60	440	-	1932	Societa
R27	PIAN PALU	NOCE	ADIGE	9III	2433	Rockfill	-	16.7	52	175	-	1951	-
R28	S. GIUSTINA	NOCE	ADIGE	10III	5834	Conc.-arch	1050	182.2	150	90	16.5	1951	Societa
R29	MOLLARO	NOCE	ADIGE	21IV	5828	Gravity	1090	0.9	22	-	-	1930	Societa
R30	ROCHETTA	NOCE	ADIGE	21IV	5922	Conc.-arch	14.2	3.0	40	-	-	1937	Societa
R31	FEDAIA WEST (5)	AVISIO	ADIGE	11II	2148	Arch-gravity	-	16.0	50	-	-	1950	-
R32	FEDAIA EAST (5)	AVISIO	ADIGE	11II	2148	Earth	-	16.0	20	-	-	1950	-
R33	FORTEBUSSO	TRAVIGNOLO	ADIGE	22IV	0731	Arch-gravity	-	27	110	330	-	1950	-
R34	LAGO DELLA PIAZZE	PINE-FERSINA	ADIGE	21II	7513	Rockfill	31.6	6.5	15	-	-	1926	Societa
R35	MORI	ADIGE	ADIGE	36IV	5580	Weir	-	-	-	-	-	1932	-
R36	PRA DA STUA	AVIANA	ADIGE	35II	4870	Arch-gravity	37.8	1.5	49	-	-	1949	-
R37	ALA	ADIGE	ADIGE	36III	5468	Weir	-	-	-	-	-	1944	Societa

NOTES:
(1) Serial number-See General Map, Plate 1
(2) AMS Series M791 - Scale: 1:50,000
(3) Reference Nos. in Bibliography
(4) Drainage area of BRESSANONE Power Plant
(5) Dams located on same reservoir
(6) Paragraph Reference Nos. in Exhibit A

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TABLE 4
SUMMARY OF DAM DATA

	Map Sheet (2)	Grid Reference	Type	Drainage Area km^2	Res. Capacity $m^3 10^6$	Height m	Length m	Width (base) m	Construction Date	Company	Source Reference Nos. (3)	Exhibit A Reference Nos. (5)
	11IV	9870	Weir	3045	-	-	-	-	-	Montecatini Group	47	A-09d(3)(a)
	11IV	9363	Weir	-	.24	-	-	-	-	Montecatini Group	49, 50	A-09d(5)(c)
	3III	1681	Earth	322	110.0	32	467	-	1951	Montecatini Group	47, 51, 52, 53, 78	A-09c(2)(a)
	3II	4077	Earth	-	25	40	300	-	1950	---	54	A-09c(5)
	9I	3656	-	1075	0.5	-	-	-	-	Societa Alto Adige	47	A-09c(4)(b)
	9I	-	Buttress	-	15	100	-	-	Under const.	Societa Alto Adige	55	A-09c(4)(a)
	9III	3042	Conc.-arch gravity	14.2	16.1	60	440	-	1932	Societa Tridentina	28, 40, 56, 57	A-09e(1)(a)
	9III	2433	Rockfill	-	16.7	52	175	-	1951	---	56, 57	A-09e(2)(b)
	10III	5834	Conc.-arch	1050	182.2	150	90	16.5	1951	Societa Edison	37, 56, 57, 58	A-09e(3)(a)
	21IV	5828	Gravity	1090	0.9	22	-	-	1930	Societa Tridentina	28, 60	A-09e(4)(b)
	21IV	5922	Conc.-arch	14.2	3.0	40	-	-	1937	Societa Tridentina	17	A-09e(5)
	11II	2148	Arch-gravity	-	16.0	50	-	-	1950	---	23, 55	A-09f(1)
	11II	2148	Earth	-	16.0	20	-	-	1950	---	23, 55	A-09f(1)
	22IV	0731	Arch-gravity	-	27	110	330	-	1950	---	61	A-09f(2)
	21II	7513	Rockfill	31.6	6.5	15	-	-	1926	Societa Tridentina	27, 55	A-09c(8)
	36IV	5580	Weir	-	-	-	-	-	1932	---	62	A-09c(9)
	35II	4870	Arch-gravity	37.8	1.5	49	-	-	1949	---	63	A-09c(10)
	36III	5468	Weir	-	-	-	-	-	1944	Societa Medio Adige	57, 64	A-09c(11)(b)

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Washington Dist., Corps of Engineers, June 1953

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TABLE 5
INUNDATION EFFECT OF STILL-WATER BARRIERS

Site No.	River Km	Location & Description	Sheet No. AMS Series M-691	UTM Grid	MW Elev. (m above m.s.l.)	Pool Elev. (m above m.s.l.)	Dimensions of Inundated Area: Length (km)	Width (km)	Area (km^2)	Avg. Depth (m)	Volume ($10^6 m^3$)	Re
		ISONZO RIVER										
1	10	RR Br. nr. PAPARIANO	40	7874	6.3	9.5	0.5	0.75	0.4	0.7	0.1	Levees intact.
						9.5			4.0	1.5	2.0	Breach right levee. Sandba
												Low point on road embankmer
		TAGLIAMENTO RIVER										
2	32	RR Br. nr. LATISANA	40	4471	River appears to be entrenched - Levees are low. Site not considered suitable for still-water barrier.							
3	59	RR Br. nr. CASELLO	39	3791	46.0	50.0	1.0	1.5	1.5	1.0	1.5	Levees intact.
					Raising pool over 50.0 would overtop left levee causing a diverted flow behind left forming terraced series of pools behind any embankments in area. Three pools evaluated:							
						50.0			1.5	1.0	1.5	
						48.5			1.0	0.3	0.3	
						43.5			1.8	0.25	0.2	
					Additional pools could probably be formed.							
		LIVENZA RIVER										
4	34	RR Br. nr. S. ANASTASIO	39	1965	River appears to be entrenched in this portion. Site not considered suitable for still-water barrier.							
5	45	RR Br. nr. MOTTA DI LIVENZA	39	1572	2.6	7.0	1.0	1.0	1.0	0.75	0.8	Breach both levees
									2.5	0.75	1.8	Breach both levees-2 road
						Additional drainage obstacles would probably be formed between CANALE MALGHER & LIVENZA R. by allowing diverted flow behind left levee.						
		PIAVE RIVER										
6	23.4	RR Br. nr. S. DONA DI PIAVE	52	0856	Insufficient data on elevations available to permit estimate of flooding effects. Flooding probably possible with pool confined by: RR Embankment on downstream side; Road Embankment 1 km from right bank; Road Embankment 1 km from left bank							
7	42.5	RR Br. nr. PONTI DE PIAVE	39	0265	4.8	8.0	1.0	3.0	3.0	Less than 1	3.0	Levees intact.
8	60	RR Br. nr. PRIULA	38	8677	66(approx.)	6.9	1.0	2.0	2.0	1.5	3.0	Left levee intact-Right 1
		BRENTA RIVER										
			At the sites considered, the river appeard to be entrenched and the sites were considered unsuitable for still-wate									
9	43.9	RR Br. at PONTI DI BRENTA	50	3034								
10	49.3	RR Br. nr. PADOVA	50	2636								
11	72.7	RR Br. at CAMPO S. MARTINO	50	1947								
12	86.0	RR Br. at FONTANIVA	50	1356								

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TABLE 5
INUNDATION EFFECT OF STILL-WATER BARRIERS

eet No. Series -691	UTM Grid	MW Elev. (m above m.s.l.)	Pool Elev. (m above m.s.l.)	Dimensions of Inundated Area: Length (km)	Width (km)	Area (km^2)	Avg. Depth (m)	Volume ($10^6 m^3$)	Remarks
40	7874	6.3	9.5	0.5	0.75	0.4	0.7	0.1	Levees intact.
			9.5			4.0	1.5	2.0	Breach right levee. Sandbag 3/4 km length of RR embankment 0.5 m high - Sandbag Low point on road embankment at 7576 (1 km long-0.5 m high).
40	4471	River appears to be entrenched - Levees are low. Site not considered suitable for still-water barrier.							
39	3791	46.0	50.0	1.0	1.5	1.5	1.0	1.5	Levees intact.
		Raising pool over 50.0 would overtop left levee causing a diverted flow behind left forming terraced series of pools behind any embankments in area. Three pools evaluated:							
			50.0			1.5	1.0	1.5	
			48.5			1.0	0.3	0.3	
			43.5			1.0	0.25	0.2	
		Additional pools could probably be formed.							
39	1965	River appears to be entrenched in this portion. Site not considered suitable for still-water barrier.							
39	1572	2.6	7.0	1.0	1.0	1.0	0.75	0.8	Breach both levees
						2.5	0.75	1.8	Breach both levees-2 road embankments and RR embankment on left side.
			Additional drainage obstacles would probably be formed between CANALE MALGHER & LIVENZA R. by allowing diverted flow behind left levee.						
52	0856	Insufficient data on elevations available to permit estimate of flooding effects. Flooding probably possible with pool confined by: RR Embankment on downstream side; Road Embankment 1 km from right bank; Road Embankment 1 km from left bank							
39	0265	4.8	8.0	1.0	3.0	3.0	Less than 1	3.0	Levees intact.
38	8677	66(approx.)	6.9	1.0	2.0	2.0	1.5	3.0	Left levee intact-Right levee breached.

At the sites considered, the river appeared to be entrenched and the sites were considered unsuitable for still-water barriers.

50	3034
50	2636
50	1947
50	1356

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TABLE 5
INUNDATION EFFECT OF STILL-WATER BARRIERS

Site No.	River Km	Location & Description	Sheet No. AMS Series M-691	MW Elev. Lower End	MW Elev. Upper End	Pool Elevation	Dimensions of Inundated Area: Length River Km	Width Max. Km	Width Min. Km	Area (km^2)	Avg. Depth (m)	Volume ($10^6 m^3$)	
		ADIGE RIVER											
	0.0-25	(Mouth to CAVARZERE)	65	Land is generally below sea level and could be flooded from either River or Sea.									
13	25-39		64,65	3.25	6.25	2.5	14	6.0	2.5	60	1.0	60	RR Em
14	42.5-51.5		64	7.0	8.8	5.0	9	5.0	2.0	24	1.5	36	Rd. E
15	51.5-61.0		64	8.8	10.5	6.0	9.5	3.0	1.75	23	1.5	36	Rd. E RR E
16	61.0-64.0		64	10.5	11.1	7.0	3	1.5	0.75	5	1.0	5	Rd. E
17	64.0-75.5		64	11.1	13.2	8.0	11.5	2.5	0.5	22	1.0	22	Rd. E
18	75.5-82.5		63,64	13.2	14.4	12.0	7.0	1.5	0.5	5	1.0	5	Rd. E
19	82.5-96		63	14.4	16.8	14.0	13.5	2.0	0.75	15	1.0	15	Canal RR Em

NOTES:

1. Pools similar to the above could probably be formed on the left side by breaching left levees. Below km 75.5, such pools would be confined on the north by CANALE GORZONE 1-4 km from ADIGE.
2. The area South and East of LEGNAGO (sheet 63-I, GR8207) is artificially drained. Destruction of drainage facilities would probably swamp that area.
3. CANALE BIANCO & TARTARO R. could probably be used as supplementary sources of water to flood area between the right bank pools and the north bank of the PO.

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TABLE 5
INUNDATION EFFECT OF STILL-WATER BARRIERS

Sheet No. AMS Series M-691	MW Elev.			Dimensions of Inundated Area						Remarks
	Lower End	Upper End	Pool Elevation	Length River Km	Width Max. Km	Width Min. Km	Area (km^2)	Avg. Depth (m)	Volume ($10^6 m^3$)	
65	Land is generally below sea level and could be flooded from either River or Sea.									
64,65	3.25	6.25	2.5	14	6.0	2.5	60	1.0	60	RR Embankment on East-NAVIGLIO ADIGETTO Levees on South.
64	7.0	8.8	5.0	9	5.0	2.0	24	1.5	36	Rd. Embankment on East and South.
64	8.8	10.5	6.0	9.5	3.0	1.75	23	1.5	36	Rd. Embankment on East. RR Embankment on South.
64	10.5	11.1	7.0	3	1.5	0.75	5	1.0	5	Rd. Embankment South and East.
64	11.1	13.2	8.0	11.5	2.5	0.5	22	1.0	22	Rd. Embankment South and East.
63,64	13.2	14.4	12.0	7.0	1.5	0.5	5	1.0	5	Rd. Embankment South and East.
63	14.4	16.8	14.0	13.5	2.0	0.75	15	1.0	15	Canal Embankment on East RR Embankment on South

probably be formed on the left side by breaching
uch pools would be confined on the north by CANALE

GO (sheet 63-I, GR8207) is artificially drained.
ties would probably swamp that area.
probably be used as supplementary sources of
e right bank pools and the north bank of the PO.

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TABLE 6
SUMMARY OF EFFECTS OF ARTIFICIAL FLOW VARIATIONS

Flood No.	a. River Basin b. Dam c. Type of Outflow	Location (1)	Station No. (1)	River km	Map Sheet (2)	Grid	Discharge (m3/sec) Initial	Increase	Crest	River Depth (m) Initial	Increase	Crest	Crest(3) Overflow Depth(m)	River Width(km) Initial	Crest	Mean Veloci[ty] Initia[l]
1	a. TAGLIAMENTO R.	LUMIEI DAM	R4	153	13II	2546	0	610	610	-	-	-	-	-	-	-
	b. LUMIEI DAM	PLAN DEL SAC	G7	144	13II	2940	5	575	580	-	-	-	-	-	-	-
	c. Outlet Discharge:	INVILLINA	G8	130	13II	4041	20	540	560	1.0	1.5	2.5	1.0	0.1	0.7	0.7
	(1 emergency &	PIOVERNO	G9	109	14III	5633	90	505	595	1.0	1.0	2.0	0.5	0.1	0.4	1.9
	3 scour outlets)	PONTE DI PINZANO	G10	89	25IV	4216	110	480	590	2.0	1.5	3.5	Bankfull	0.1	0.2	0.7
		PASSO CANUSSIO	G11	45	40IV	4278	120	450	570	2.0	2.0	4.0	0.5	0.1	0.4	0.7
2	a. PIAVE R.	PIEVE D'CADORE DAM	R11	177	12II	9944	0	500	500	-	-	-	-	-	-	-
	b. PIEVE D'CADORE DAM	nr. PERAROLO	-	172	12II	9641	30	470	500	-	-	-	-	-	-	-
	c. Outlet Discharge:	nr. BELLUNO	-	128	23III	8211	60	420	480	3.5	3.0	6.5	2.5	0.1	0.2	1.1
	(2 scour outlets)	SEGUSINO	G19	95	37I	2889	90	390	480	1.5	1.5	3.0	0.5	0.1	0.2	0.8
		NERVESA	G20	63.5	38II	8378	100	360	460	1.5	0.5	2.0	Bankfull	0.2	0.7	0.8
		PONTE D'PIEVE	G21	42.5	39III	0165	120	340	460	2.5	1.0	3.5	0.5	0.2	1.5	0.6
3	a. ADIGE R.	S. VALENTINO DAM	R22	399	3III	1681	0	430	430	-	-	-	-	-	-	-
	b. S. VALENTINO DAM	nr. GORENZA	-	388	3III	1770	5	410	415	-	-	-	-	-	-	-
	c. Outlet Discharge:	nr. MERANO	-	338	10IV	6568	10	345	355	0.5	4.5	5.0	1.0	0.05	0.6	0.1
	(2 outlets)	PONTE ADIGE	G28	312	10II	7650	20	320	340	1.5	5.0	6.5	Bankfull	0.05	0.1	0.5
		NOCE & ADIGE R.	-	267	21III	6012	200	290	490	-	-	-	-	-	-	-
		TRENTO	G31	253	21III	6304	210	285	495	3.0	1.0	4.0	Bankfull	0.1	0.3	0.8
		SERRAVILLE	G32	218	36III	5675	220	270	490	2.0	2.0	4.0	Within Banks	0.1	0.1	0.6
		PASCATINA	G33	168	48II	4538	240	245	485	2.5	0.5	3.0	Within Banks	0.2	0.2	1.1
		ALBERDO D'ADIGE	G34	114	63I	7721	250	215	465	2.5	0.5	3.0	Bankfull	0.3	0.6	0.6
4	a. ADIGE R.	S. GIUSTINA DAM	R28	294	10III	5834	0	1000	1000	-	-	-	-	-	-	-
	b. S. GIUSTINA DAM	NOCE & ADIGE R.	-	267	21III	6012	200	745	945	-	-	-	-	-	-	-
	c. Outlet Discharge:	TRENTO	G31	253	21III	6304	210	610	820	3.0	2.0	5.0	1.0	0.1	0.4	0.8
	(2 scour outlets	SERRAVILLE	G32	218	36III	5675	220	530	750	2.0	4.0	6.0	Within Banks	0.1	0.1	0.6
	& spillway)	PESCATINA	G33	168	48II	4538	240	460	700	2.5	1.5	4.0	Bankfull	0.2	0.3	1.1
		ALBERDO D'ADIGE	G34	114	63I	7721	250	390	640	2.5	1.0	3.5	0.5	0.3	0.9	0.6

NOTES:

(1) See Table 3 for additional data on gaging stations & Table 4 for data on dams & Plate 1 for location on general map
(2) AMS Map Series M791, scale 1:50,000
(3) Approximate height of crest above average top of bank in vicinity
(4) Assuming major levees intact and not overtopped

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TABLE 6
SUMMARY OF EFFECTS OF ARTIFICIAL FLOW VARIATIONS

Station No. (1)	River km	Map Sheet (2)	Grid	Discharge (m3/sec) Initial	Discharge Increase	Discharge Crest	River Depth (m) Initial	River Depth Increase	River Depth Crest	Crest(3) Overflow Depth(m)	River Width(km) Initial	River Width Crest	Mean Surface Velocity(m/sec) Initial	Mean Surface Velocity Crest	Time (Hr.) Start of Rise	Time Crest	Duration Above Top of Bank (Days)
R4	153	13II	2546	0	610	610	-	-	-	-	-	-	-	-	0	0	2.0
G7	144	13II	2940	5	575	580	-	-	-	-	-	-	-	-	0.5	4	2.0
G8	130	13II	4041	20	540	560	1.0	1.5	2.5	1.0	0.1	0.7	0.7	1.0	1	6	2.0
G9	109	14III	5633	90	505	595	1.0	1.0	2.0	0.5	0.1	0.4	1.9	2.8	3	14	1.5
G10	89	25IV	4216	110	480	590	2.0	1.5	3.5	Bankfull	0.1	0.2	0.7	1.2	10	24	0
G11	45	40IV	4278	120	450	570	2.0	2.0	4.0	0.5	0.1	0.4	0.7	1.5	18	34	1.5
R11	177	12II	9944	0	500	500	-	-	-	-	-	-	-	-	0	0	1.5
-	172	12II	9641	30	470	500	-	-	-	-	-	-	-	-	0.5	10	1.5
-	128	23III	8211	60	420	480	3.5	3.0	6.5	2.5	0.1	0.2	1.1	1.5	2	24	2.0
G19	95	37I	2889	90	390	480	1.5	1.5	3.0	0.5	0.1	0.2	0.8	1.3	5	32	2.0
G20	63.5	38II	8378	100	360	460	1.5	0.5	2.0	Bankfull	0.2	0.7	0.8	1.0	11	45	0
G21	42.5	39III	0165	120	340	460	2.5	1.0	3.5	0.5	0.2	1.5	0.6	0.7	15	53	2.0
R22	399	3III	1681	0	430	430	-	-	-	-	-	-	-	-	0	0	5.0
-	388	3III	1770	5	410	415	-	-	-	-	-	-	-	-	0.5	5	5.0
-	338	10IV	6568	10	345	355	0.5	4.5	5.0	1.0	0.05	0.6	0.1	0.8	4	38	3.5
G28	312	10II	7650	20	320	340	1.5	5.0	6.5	Bankfull	0.05	0.1	0.5	1.1	10	50	0
-	267	21III	6012	200	290	490	-	-	-	-	-	-	-	-	18	63	-
G31	253	21III	6304	210	285	495	3.0	1.0	4.0	Bankfull	0.1	0.3	0.8	0.9	22	67	0
G32	218	36III	5675	220	270	490	2.0	2.0	4.0	Within Banks	0.1	0.1	0.6	1.2	32	77	0
G33	168	48II	4538	240	245	485	2.5	0.5	3.0	Within Banks	0.2	0.2	1.1	1.3	40	90	0
G34	114	63I	7721	250	215	465	2.5	0.5	3.0	Bankfull	0.3	0.6	0.6	0.7	56	113	0
R28	294	10III	5834	0	1000	1000	-	-	-	-	-	-	-	-	0	0	7.0
-	267	21III	6012	200	745	945	-	-	-	-	-	-	-	-	2	5	-
G31	253	21III	6304	210	610	820	3.0	2.0	5.0	1.0	0.1	0.4	0.8	1.0	4	10	2.5
G32	218	36III	5675	220	530	750	2.0	4.0	6.0	Within Banks	0.1	0.1	0.6	1.5	9	32	0
G33	168	48II	4538	240	460	700	2.5	1.5	4.0	Bankfull	0.2	0.3	1.1	1.4	19	52	0
G34	114	63I	7721	250	390	640	2.5	1.0	3.5	0.5	0.3	0.9	0.6	0.7	32	79	3.0

gaging stations & Table 4 for data on dams & Plate 1 for location on general map

verage top of bank in vicinity
t overtopped

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TABLE 7
SUMMARY OF EFFECTS OF ARTIFICIAL MAJOR FLOOD WAVES

Flood No.	a. River b. Dam c. Type of Outflow	Location (1)	Station No. (1)	River km	Map Sheet (2)	Grid	Discharge (m3/sec) Initial	Discharge (m3/sec) Increase	Discharge (m3/sec) Crest	River Depth (m) Initial	River Depth (m) Increase	River Depth (m) Crest	Crest(3) Overflow Depth(m)	River Width(km) Initial	River Width(km) Crest	Mea Veloc Initi
5	a. TAGLIAMENTO R.	LUMIEI DAM	R4	153	13II	2546	0	8500	8500	-	-	-	-	-	-	-
	b. LUMIEI DAM	PLAN DEL SAC	G7	144	13II	2940	5	4080	4085	-	-	-	-	-	-	-
	c. Type A Breach	INVILLINA	G8	130	13II	4041	20	2460	2480	1.0	3.0	4.0	2.5	0.1	1.0	0.7
	(Parabolic,	PIOVERNO	G9	109	14III	5633	90	1730	1820	1.0	1.5	2.5	1.0	0.1	0.7	1.9
	23 m deep)	PONTE DI PINZANO	G10	89	25IV	4216	110	1530	1640	2.0	3.5	5.5	0.5	0.1	0.4	0.7
		PASSO CANUSSIO	G11	45	40IV	4278	120	1180	1300	2.0	3.0	5.0	1.5	0.1	1.5	0.7
6	a. TAGLIAMENTO R.	LUMIEI DAM	R4	153	13II	2546	0	14600	14600	-	-	-	-	-	-	-
	b. LUMIEI DAM	PLAN DEL SAC	G7	144	13II	2940	5	10100	10105	-	-	-	-	-	-	-
	c. Type B-1 Breach	INVILLINA	G8	130	13II	4041	20	7820	7840	1.0	5.0	6.0	4.5	0.1	1.5	0.7
	(Circular,	PIOVERNO	G9	109	14III	5633	90	5250	5340	1.0	2.0	3.0	1.5	0.1	2.0	1.9
	30 m diameter)	PONTE DI PINZANO	G10	89	25IV	4216	110	4890	5000	2.0	5.5	7.5	2.5	0.1	0.7	0.7
		PASSO CANUSSIO	G11	45	40IV	4278	120	3510	3630	2.0	3.5	5.5	2.0	0.1	2.5	0.7
7	a. PIAVE R.	PIEVE D'CADORE DAM	R11	177	12II	9944	0	8500	8500	-	-	-	-	-	-	-
	b. PIEVE D'CADORE DAM	nr. PERARDO	-	172	12II	9641	30	3550	3580	-	-	-	-	-	-	-
	c. Type A Breach	nr. BELLUNO	-	128	23III	8211	60	1560	1620	3.5	6.0	9.5	6.5	0.1	0.4	1.1
	(Parabolic,	SEGUSINO	G19	95	37I	2889	90	1280	1370	1.5	3.0	4.5	2.5	0.1	0.3	0.8
	23 m deep)	NERVESA	G20	63.5	38II	8378	100	1030	1130	1.5	1.5	3.0	1.0	0.2	0.9	0.8
		PONTE D'PIAVE	G21	42.5	39III	0165	120	930	1050	2.5	1.5(4)	4.0(4)	1.5(4)	0.2	1.5(4)	0.6
8	a. ADIGE R.	S. VALENTINO DAM	R22	399	3III	1681	0	2600	2600	-	-	-	-	-	-	-
	b. S. VALENTINO DAM	nr. GORENZA	-	388	3III	1770	5	2140	2145	-	-	-	-	-	-	-
	c. Type C Breach	nr. MERANO	-	338	10IV	6568	10	1220	1230	0.5	6.0	6.5	2.5	0.05	1.2	0.1
	(Parabolic,	PONTE ADIGE	G28	312	10II	7650	20	970	990	1.5	7.0	8.5	1.5	0.05	1.3	0.5
	eroded from	NOCE & ADIGE R.	-	267	21III	6012	200	740	960	-	-	-	-	-	-	-
	initial 5 m deep	TRENTO	G31	253	21III	6304	210	690	900	3.0	2.5	5.5	1.5	0.1	0.5	0.8
	to final 20 m	SERRAVILLE	G32	218	36III	5675	220	630	850	2.0	4.5	6.5	Within Banks	0.1	0.1	0.6
	deep in 4.5 hrs.)	PESCATINA	G33	168	48II	4538	240	550	790	2.5	1.5	4.0	Bankfull	0.2	0.3	1.1
		ALBERDO D'ADIGE	G34	114	63I	7721	250	460	710	2.5	1.0	3.5	0.5	0.3	1.2	0.6
9	a. ADIGE R.	S. GIUSTINA DAM	R28	294	10III	5834	0	8500	8500	-	-	-	-	-	-	-
	b. S. GIUSTINA DAM	NOCE & ADIGE R.	-	267	21III	6012	200	5350	5550	-	-	-	-	-	-	-
	c. Type A Breach	TRENTO	G31	253	21III	6304	210	2590	2800	3.0	5.5	8.5	4.5	0.1	0.8	0.8
	(Parabolic,	SERRAVILLE	G32	218	36III	5675	220	2030	2250	2.0	9.5	11.5	1.5	0.1	0.3	0.6
	23 m deep)	PESCATINA	G33	168	48II	4538	240	1620	1860	2.5	3.0	5.5	1.5	0.2	0.4	1.1
		ALBERDO D'ADIGE	G34	114	63I	7721	250	1250	1500	2.5	1.5(4)	4.0(4)	1.0(4)	0.3	2.0(4)	0.6
10	a. ADIGE R.	S. GIUSTINA DAM	R28	294	10III	5834	0	12400	12400	-	-	-	-	-	-	-
	b. S. GIUSTINA DAM	NOCE & ADIGE R.	-	267	21III	6012	200	8320	8520	-	-	-	-	-	-	-
	c. Type B-2 Breach	TRENTO	G31	253	21III	6304	210	5660	5670	3.0	7.0	10.0	6.0	0.1	1.0	0.8
	(Circular,	SERRAVILLE	G32	218	36III	5675	220	4530	4750	2.0	12.5	14.5	4.5	0.1	0.7	0.6
	25 m diameter)	PESCATINA	G33	168	48II	4538	240	3670	3910	2.5	5.5	8.0	4.0	0.2	0.6	1.1
		ALBERDO D'ADIGE	G34	114	63I	7721	250	2910	3160	2.5	2.0(4)	4.5(4)	1.5(4)	0.3	2.5(4)	0.6

NOTES: See Table 6

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TABLE 7
SUMMARY OF EFFECTS OF ARTIFICIAL MAJOR FLOOD WAVES

Station No. (1)	River km	Map Sheet (2)	Grid	Discharge (m3/sec) Initial	Discharge Increase	Discharge Crest	River Depth (m) Initial	River Depth Increase	River Depth Crest	Crest(3) Overflow Depth(m)	River Width(km) Initial	River Width Crest	Mean Surface Velocity(m/sec) Initial	Velocity Crest	Time (Hr.) Start of Rise	Time Crest	Duration Above Top of Bank (Days)
R4	153	13II	2546	0	8500	8500	-	-	-	-	-	-	-	-	0	0	1.0
G7	144	13II	2940	5	4080	4085	-	-	-	-	-	-	-	-	0.1	0.5	0.5
G8	130	13II	4041	20	2460	2480	1.0	3.0	4.0	2.5	0.1	1.0	0.7	1.6	0.5	1	0.25
G9	109	14III	5633	90	1730	1820	1.0	1.5	2.5	1.0	0.1	0.7	1.9	3.2	1	3	0.5
G10	89	25IV	4216	110	1530	1640	2.0	3.5	5.5	0.5	0.1	0.4	0.7	1.9	3	5	0.5
G11	45	40IV	4278	120	1180	1300	2.0	3.0	5.0	1.5	0.1	1.5	0.7	1.7	7	10	0.5
R4	153	13II	2546	0	14600	14600	-	-	-	-	-	-	-	-	0	0	0.25
G7	144	13II	2940	5	10100	10105	-	-	-	-	-	-	-	-	0.1	1	0.25
G8	130	13II	4041	20	7820	7840	1.0	5.0	6.0	4.5	0.1	1.5	0.7	2.3	0.5	2	0.25
G9	109	14III	5633	90	5250	5340	1.0	2.0	3.0	1.5	0.1	2.0	1.9	3.8	1	3	0.5
G10	89	25IV	4216	110	4890	5000	2.0	5.5	7.5	2.5	0.1	0.7	0.7	2.8	3	6	0.5
G11	45	40IV	4278	120	3510	3630	2.0	3.5	5.5	2.0	0.1	2.5	0.7	1.8	7	12	0.5
R11	177	12II	9944	0	8500	8500	-	-	-	-	-	-	-	-	0	0	1.0
-	172	12II	9641	30	3550	3580	-	-	-	-	-	-	-	-	0.5	1	1.0
-	128	23III	8211	60	1560	1620	3.5	6.0	9.5	6.5	0.1	0.4	1.1	1.8	2	8	1.0
G19	95	37I	2889	90	1280	1370	1.5	3.0	4.5	2.5	0.1	0.3	0.8	1.9	5	14	1.0
G20	63.5	38II	8378	100	1030	1130	1.5	1.5	3.0	1.0	0.2	0.9	0.8	1.2	11	21	1.0
G21	42.5	39III	0165	120	930	1050	2.5	1.5(4)	4.0(4)	1.5(4)	0.2	1.5(4)	0.6	0.8	15	26	1.0
R22	399	3III	1681	0	2600	2600	-	-	-	-	-	-	-	-	0	4	3.5
-	388	3III	1770	5	2140	2145	-	-	-	-	-	-	-	-	0.5	6	3.0
-	338	10IV	6568	10	1220	1230	0.5	6.0	6.5	2.5	0.05	1.2	0.1	1.0	4	14	1.0
G28	312	10II	7650	20	970	990	1.5	7.0	8.5	1.5	0.05	1.3	0.5	1.2	10	26	1.5
-	267	21III	6012	200	740	960	-	-	-	-	-	-	-	-	18	45	-
G31	253	21III	6304	210	690	900	3.0	2.5	5.5	1.5	0.1	0.5	0.8	1.0	22	50	1.5
G32	218	36III	5675	220	630	850	2.0	4.5	6.5	Within Banks	0.1	0.1	0.6	1.6	30	59	0
G33	168	48II	4538	240	550	790	2.5	1.5	4.0	Bankfull	0.2	0.3	1.1	1.4	40	70	0
G34	114	63I	7721	250	460	710	2.5	1.0	3.5	0.5	0.3	1.2	0.6	0.7	56	89	1.5
R28	294	10III	5834	0	8500	8500	-	-	-	-	-	-	-	-	0	0	2.0
-	267	21III	6012	200	5350	5550	-	-	-	-	-	-	-	-	1	3	-
G31	253	21III	6304	210	2590	2800	3.0	5.5	8.5	4.5	0.1	0.8	0.8	1.2	3	8	1.0
G32	218	36III	5675	220	2030	2250	2.0	9.5	11.5	1.5	0.1	0.3	0.6	1.9	7	17	1.0
G33	168	48II	4538	240	1620	1860	2.5	3.0	5.5	1.5	0.2	0.4	1.1	1.5	17	27	1.0
G34	114	63I	7721	250	1250	1500	2.5	1.5(4)	4.0(4)	1.0(4)	0.3	2.0(4)	0.6	0.8	30	42	1.0
R28	294	10III	5834	0	12400	12400	-	-	-	-	-	-	-	-	0	0	0.5
-	267	21III	6012	200	8320	8520	-	-	-	-	-	-	-	-	1	4	-
G31	253	21III	6304	210	5660	5670	3.0	7.0	10.0	6.0	0.1	1.0	0.8	1.3	3	7	0.5
G32	218	36III	5675	220	4530	4750	2.0	12.5	14.5	4.5	0.1	0.7	0.6	2.0	7	15	0.5
G33	168	48II	4538	240	3670	3910	2.5	5.5	8.0	4.0	0.2	0.6	1.1	1.7	15	24	1.0
G34	114	63I	7721	250	2910	3160	2.5	2.0(4)	4.5(4)	1.5(4)	0.3	2.5(4)	0.6	0.9	25	36	1.5

Prepared by Military Hydrology R&D Branch
Washington Dist., Corps of Engineers, June 1953

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TABLE 8

LOAD CHARACTERISTICS OF U. S. ARMY FOATING BRIDGES

LOAD CLASS (TONS) OF FLOATING BRIDGES (by VELOCITY, by TYPE, by RELATIVE CROSSING SAFETY)

Type	Status (1952)	Relative Crossing Safety																Velocity to destroy with no Load (fps)
		Safe						Caution					Risk					
		Maximum Surface Velocity fps / m/sec						Maximum Surface Velocity fps / m/sec					Maximum Surface Velocity fps / m/sec					
		0	3	5	7	9	11	3	5	7	9	11	3	5	7	9	11	
		0	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	0.92	1.5	2.1	2.7	3.4	
M2 Assault Boat Bridge (Normal Construction)	Standard	8	8	6	5	-	-	8	6	5	-	-	9	7	6	-	-	10
M2 Assault Boat Bridge (Reinforced Construction)	Standard	13	13	9	7	-	-	13	11	8	-	-	14	12	9	-	-	9
Widened Steel Treadway Br.	Standard	50	50	50	40	30	15	50	50	45	35	20	55	55	50	45	30	14
50-T (Divisional Airborne)	Standard	50	45	35	30	10	-	50	40	35	15	-	55	50	45	25	-	12
M4 (Normal Construction) (15' Bay)	Standard	55	55	55	55	45	30	60	60	60	50	40	65	65	65	55	45	16
Steel Class 60 Floating Br.	Standard	60	60	60	55	50	15	65	65	60	55	30	75	75	70	65	45	-
M4 (Reinforced Construction) (7½' Bay)**	Standard	95*	95*	95*	95*	70	40	100*	100*	100*	85	55	105*	105*	105*	100	70	16
M4-T6	Developmental	55	50	50	50	35	15	(No further data)										-
Aluminum Class 60 Floating Br.	Developmental	70	70	70	65	55	45	(No further data)										

*Tank data (limited by width of roadway and width of tank)
**(100% reinforced, with full Pontoons)

SOURCES:
(1) Ref 87
(2) Ref 88
(3) Misc data Engr. R&D Lab. Engr. Center, Ft. Belvoir

Prepared by Military Hydrology R&D Branch
Washington District, Corps of Engineers, Nov. 1952

TABLE 8

PLATES

1. General Map

2. Physiographic Diagram

3. River Profiles
   a. ISONZO R.
   b. TAGLIAMENTO R.
   c. LIVENZA R.
   d. PIAVE R.
   e. BRENTA R.
   f. ADIGE R. Km 265-Km 407
   g. ADIGE R. Km 0-Km 267

4. Monthly Mean Stage and Discharge
   a. ISONZO R. at CANALE DI ISONZO, PONTE DI SALCANO, and PIERIS. CORNO R. at PORTO NOGARO. STELLA R. at CASALE SACILE.
   b. STELLA R. at PRECENICCO. TAGLIAMENTO R. at PONTE DI PINZANO, FRAFOREANO, and LATISANA, LIVENZA R. at FIASCHETTI.
   c. MEDUNA R. at PONTE MEDUNA. LIVENZA R. at S. CASSIANO and MOTTA DI LIVENZA. PIAVE R. at NERVESA and PONTE DI PIAVE.
   d. BRENTA R. at SARSON, LIMENA and CORTE. BACCHIGLIONE R. at VICENZA and S. MARCO.
   e. ADIGE R. at ALBEREDO D'ADIGE, BADIA POLESINE, BOARA PISANI, CAVAZERRE, and CAVANELLA D'ADIGE.

5. Stage Duration. ISONZO R. at PONTE DI SALCANO. CORNO R. at PORTO NOGARO. TAGLIAMENTO R. at PONTE DI PINZANO and LATISANA. LIVENZA R. at S. CASSIANO and MOTTA DI LIVENZA. BRENTA R. at LIMENA.

6. Discharge Duration. ISONZO R. at CANALE DI ISONZO and SAGRADO. STELLA R. at CASALE SACILE. LIVENZA R. Basin at CANEVA, PORDENONE, PONTE MEDUNA, and MOLINO power plants. PIAVE R. at SEGUSINO. BRENTA R. at SARSON. BACCHIGLIONE R. at MONTEGALDELLA. ADIGE R. at BOARA PISANI.

7. Discharge and Velocity Rating Curves
   a. TAGLIAMENTO R.
   b. PIAVE R.
   c. ADIGE R.

8. Sketches of Dams
   a. LUMIEI
   b. PIEVE DI CADORE
   c. S. VALENTINO
   d. S. GIUSTINA

PLATES (Continued)

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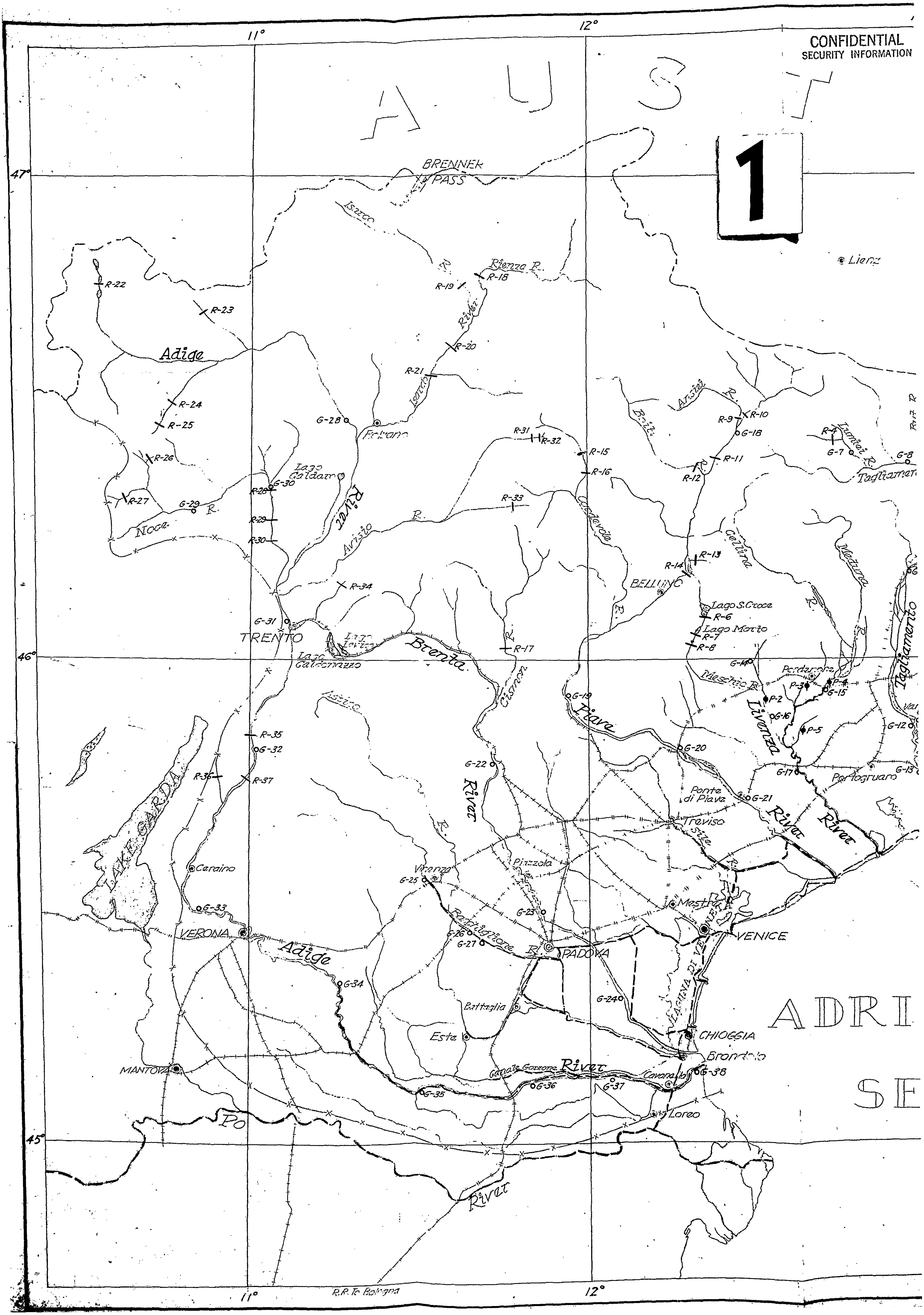

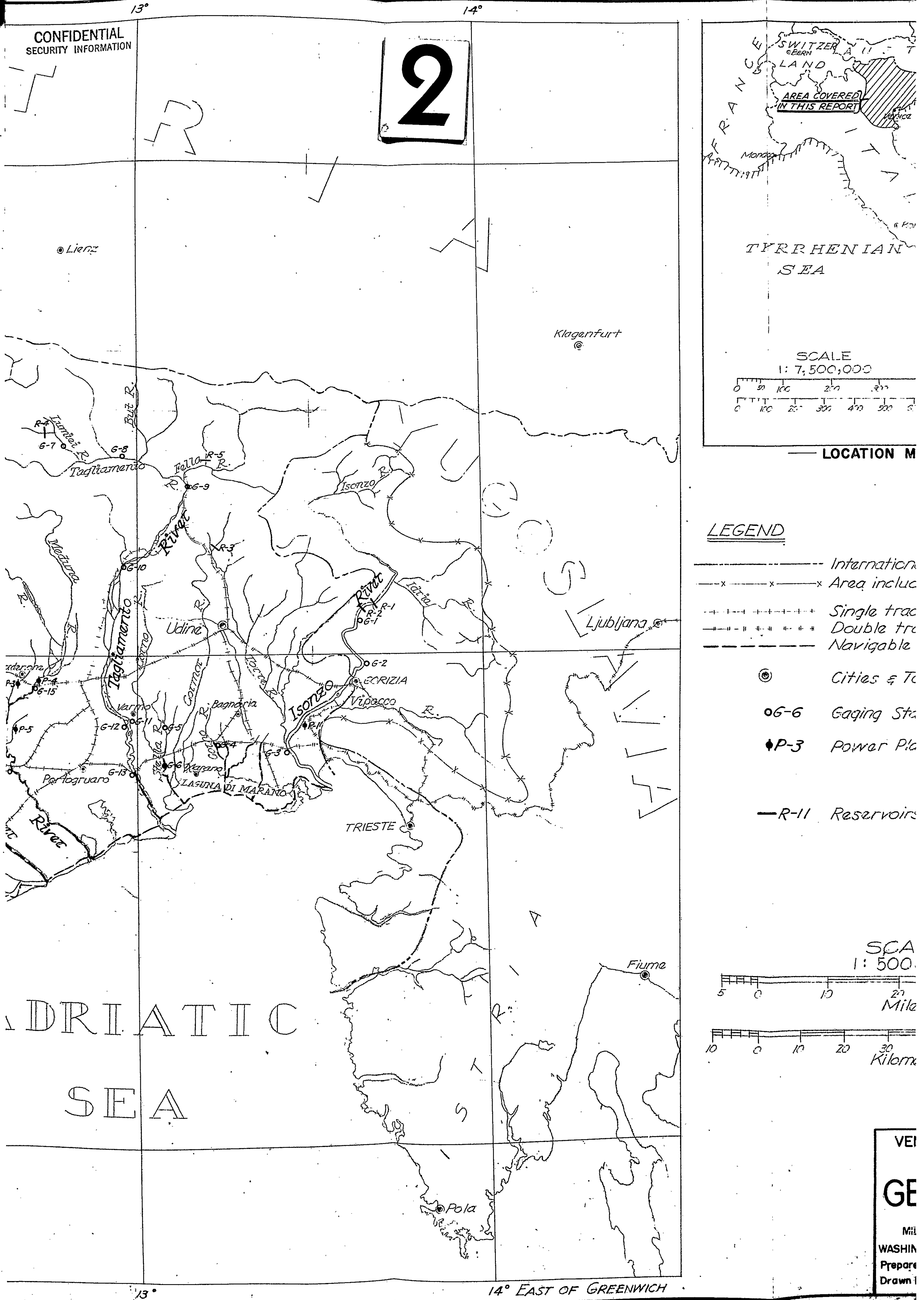

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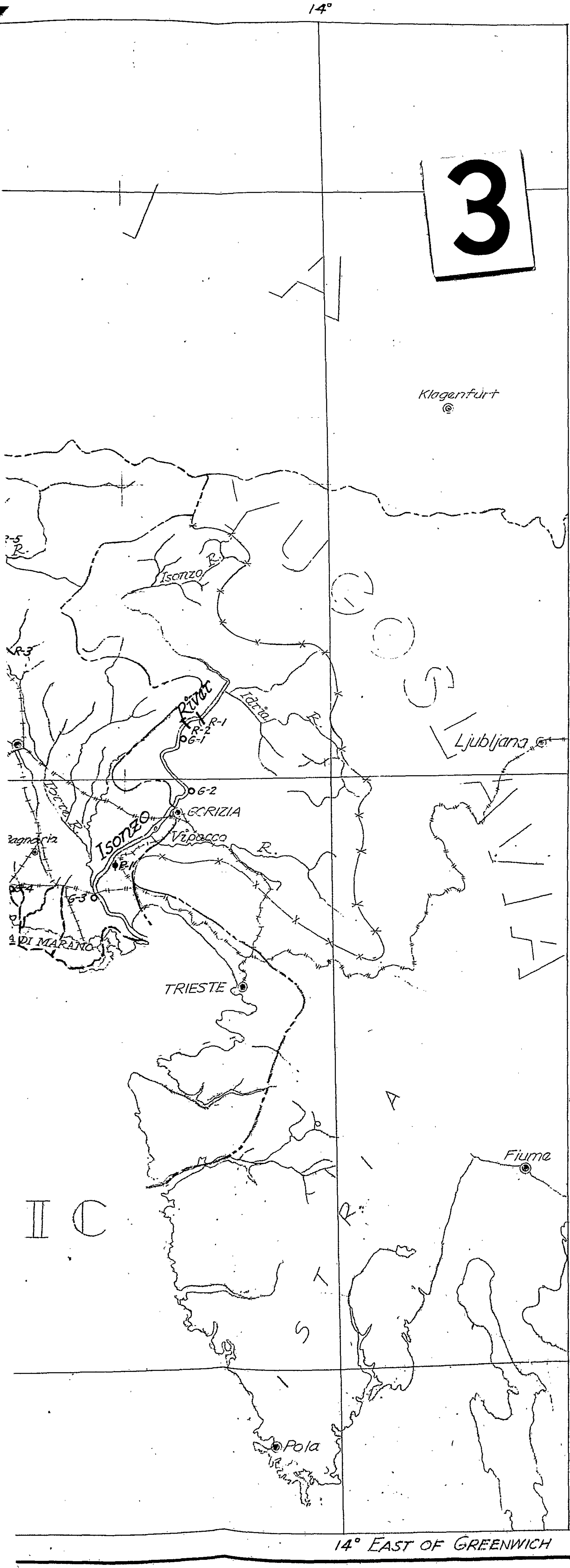
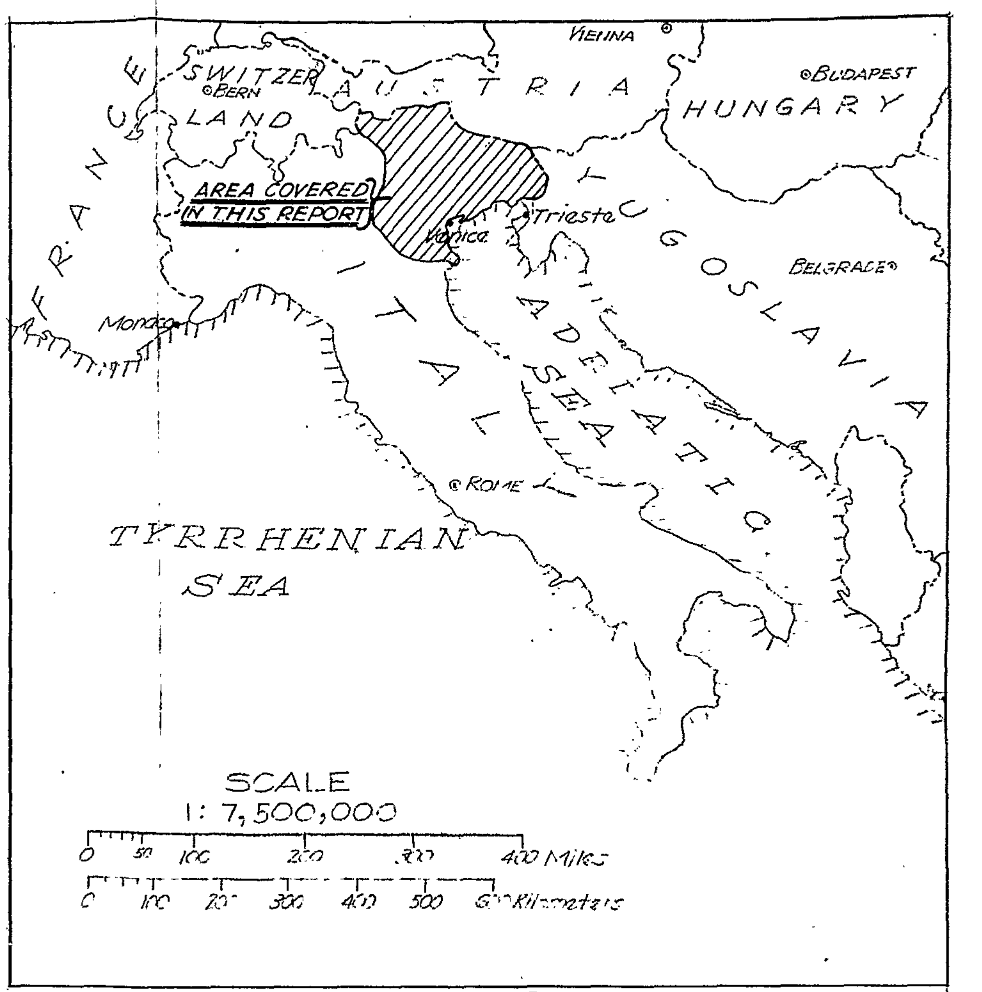
2
13°
14°
Lienz
Klagenfurt
Ljubljana
Udine
GORIZIA
TRIESTE
Fiume
Pola
Varmo
Bagnaria
Marano
Portogruaro
Vipacco R.
LAGUNA DI MARANO
Tagliamento River
Tagliamento
Fella R.
But R.
Lumiei R.
Isonzo R.
Isonzo River
Idria R.
Meduna R.
Corno R.
Cormor R.
Torre R.
ADRIATIC SEA
R-1
R-2
R-3
R-4
R-5
G-1
G-2
G-3
G-4
G-5
G-6
G-7
G-8
G-9
G-10
G-11
G-12
G-13
G-15
P-3
P-4
P-5
P-11
SWITZERLAND
BERN
FRANCE
AREA COVERED IN THIS REPORT
Venice
Monaco
TYRRHENIAN SEA
SCALE
1: 7,500,000
LOCATION M
LEGEND
Internationa
Area inclu
Single trac
Double tra
Navigable
Cities & To
G-6 Gaging Sta
P-3 Power Pla
R-11 Reservoirs
SCA
1: 500
Mile
Kilom
VE
GE
WASHIN
Prepare
Drawn
13°
14° EAST OF GREENWICH





LOCATION MAP

LEGEND

International Boundary
Area included in this report
Single track R.R.
Double track R.R.
Navigable Waterways
Cities & Towns
G-6 Gaging Stations
P-3 Power Plants (Only those which furnish discharge data pertinent to this report.)
R-11 Reservoirs

SCALE
1: 500,000

5 0 10 20 30 40 50
Miles

10 0 10 20 30 40 50 60 70 80
Kilometers

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VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

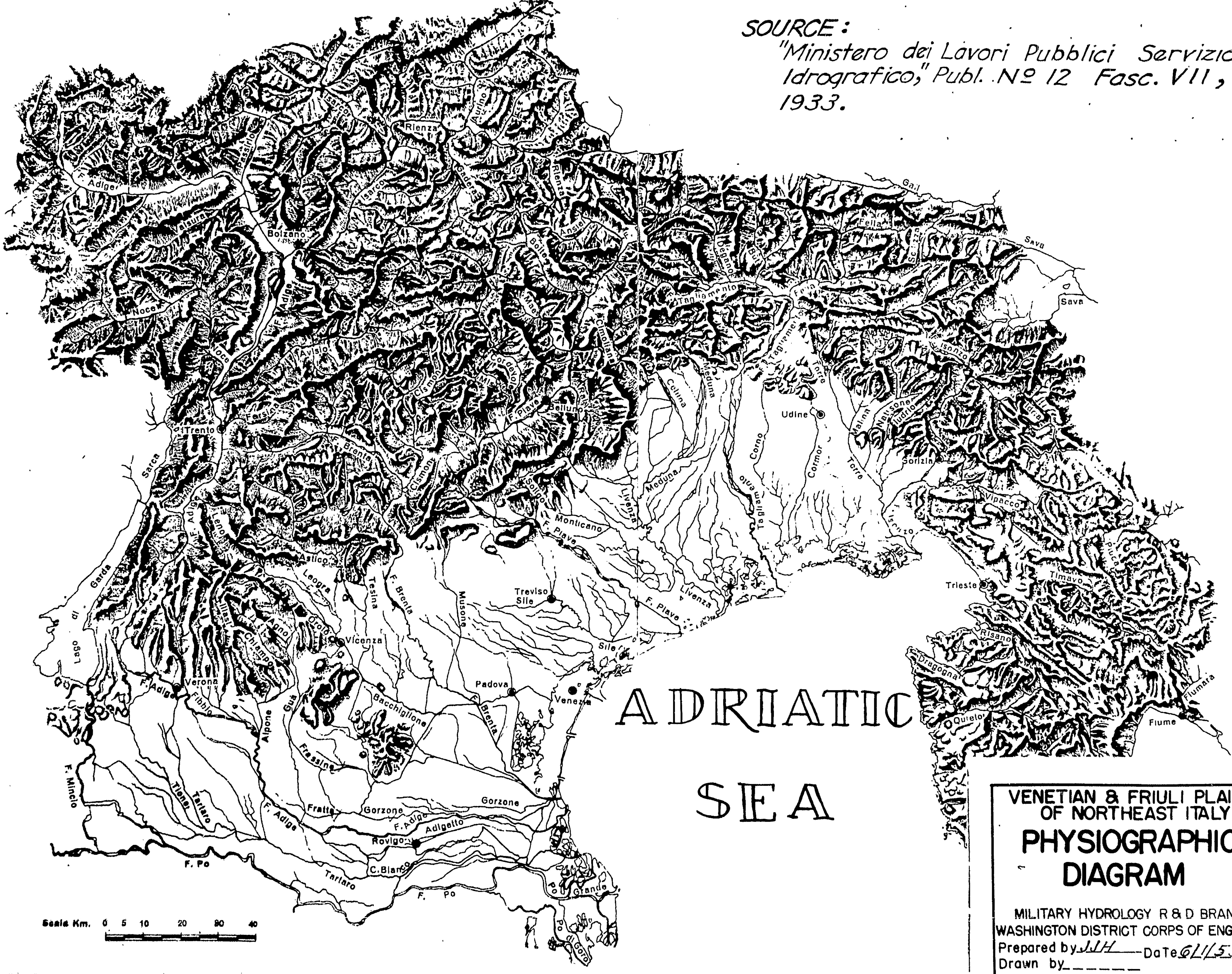
GENERAL MAP

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by HAE Date July 1953
Drawn by JJH

PLATE 1

SOURCE:
"Ministero dei Lavori Pubblici Servizio Idrografico," Publ. № 12 Fasc. VII, 1933.



VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

PHYSIOGRAPHIC DIAGRAM

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH DaTe 6/1/53
Drawn by______

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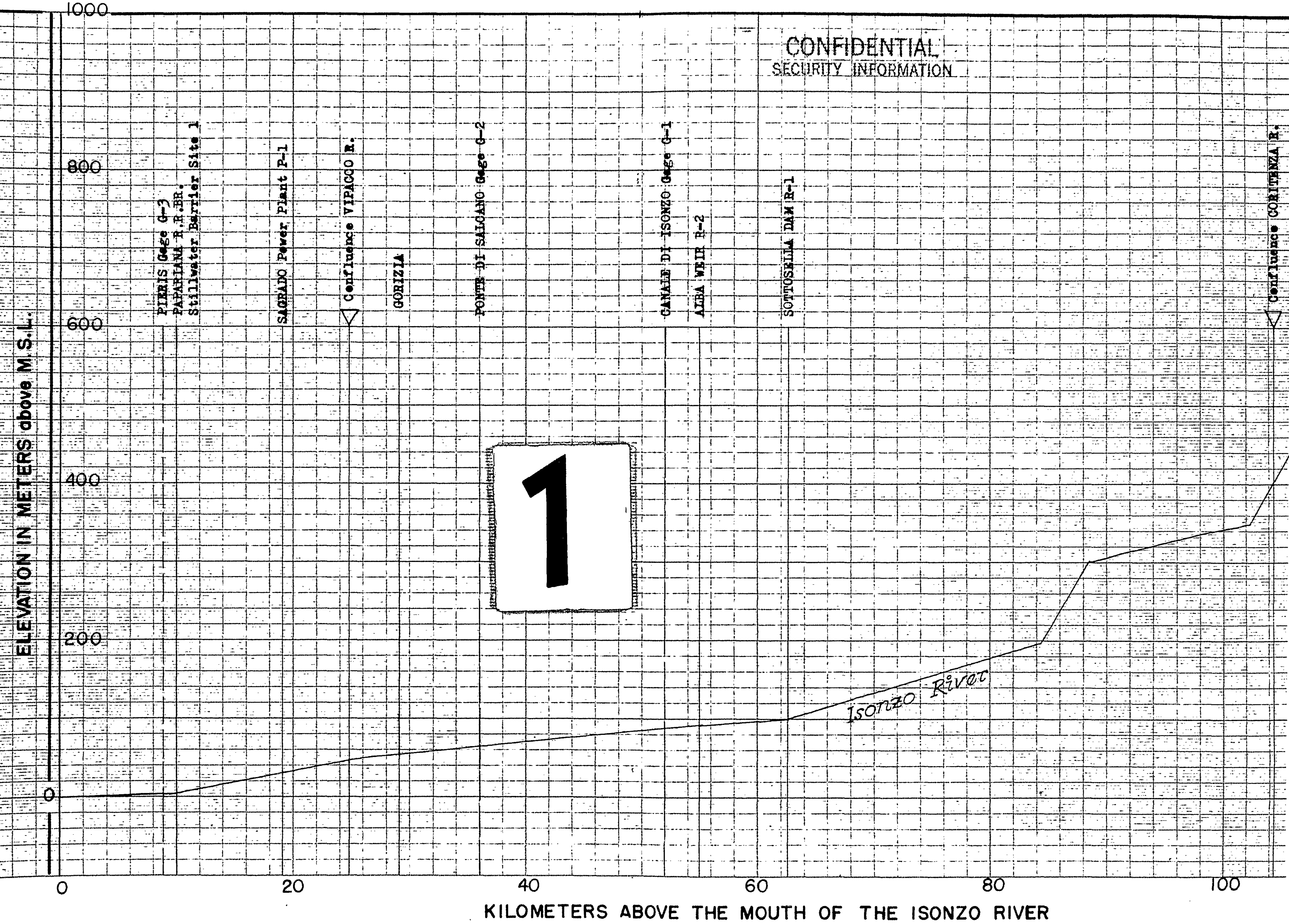

1

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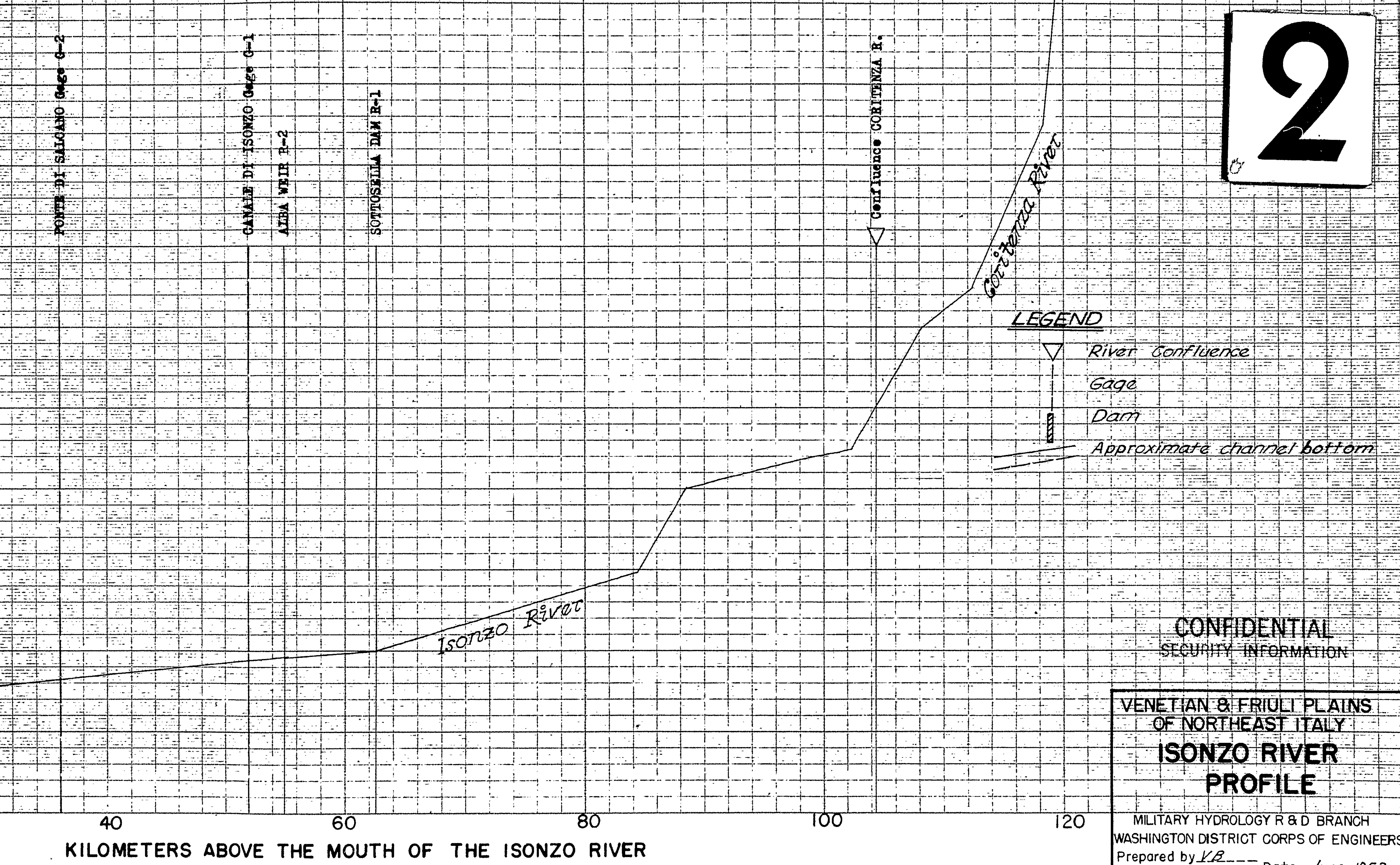

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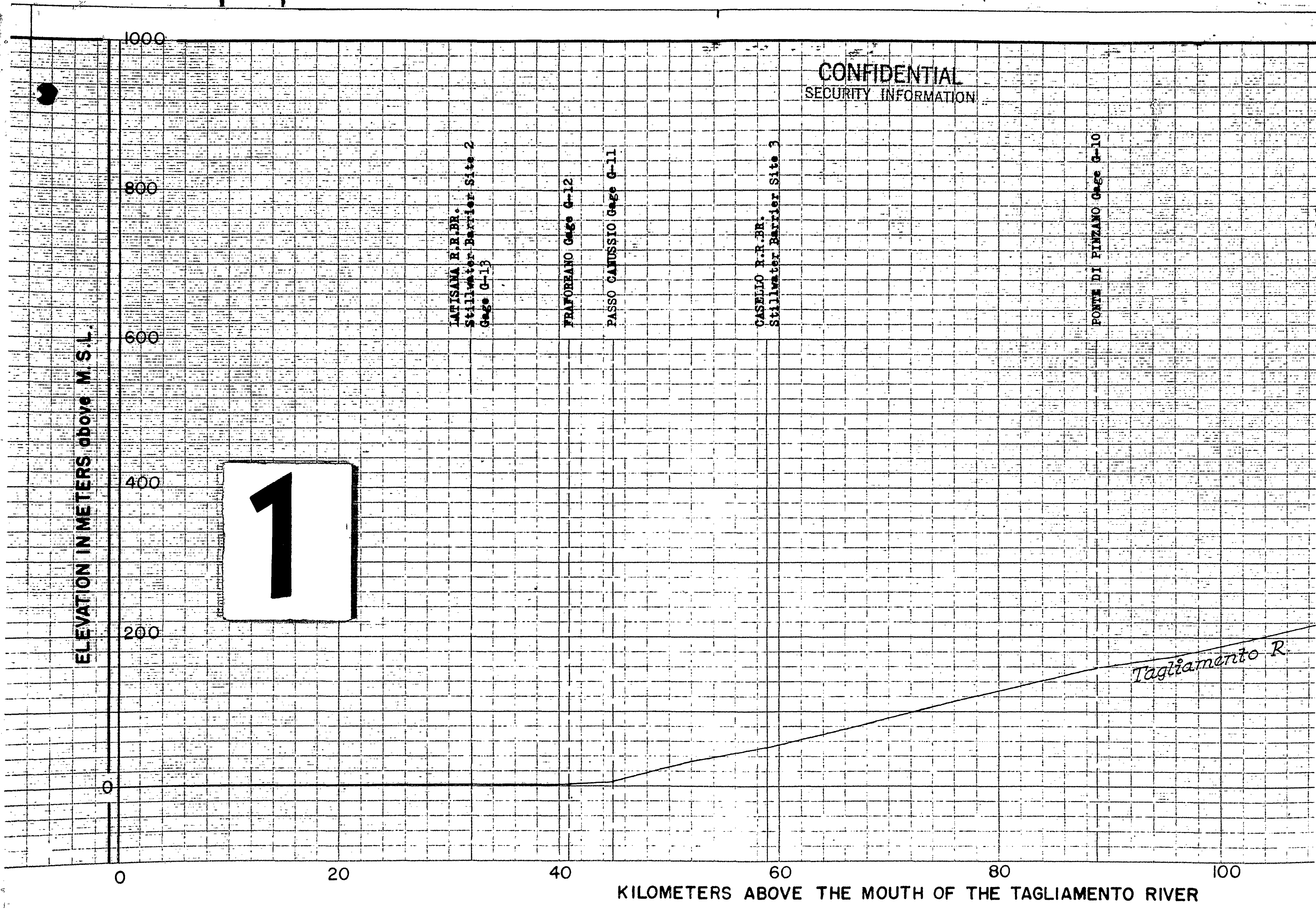
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

ISONZO RIVER PROFILE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date June 1953
Drawn by JJH

PLATE 3a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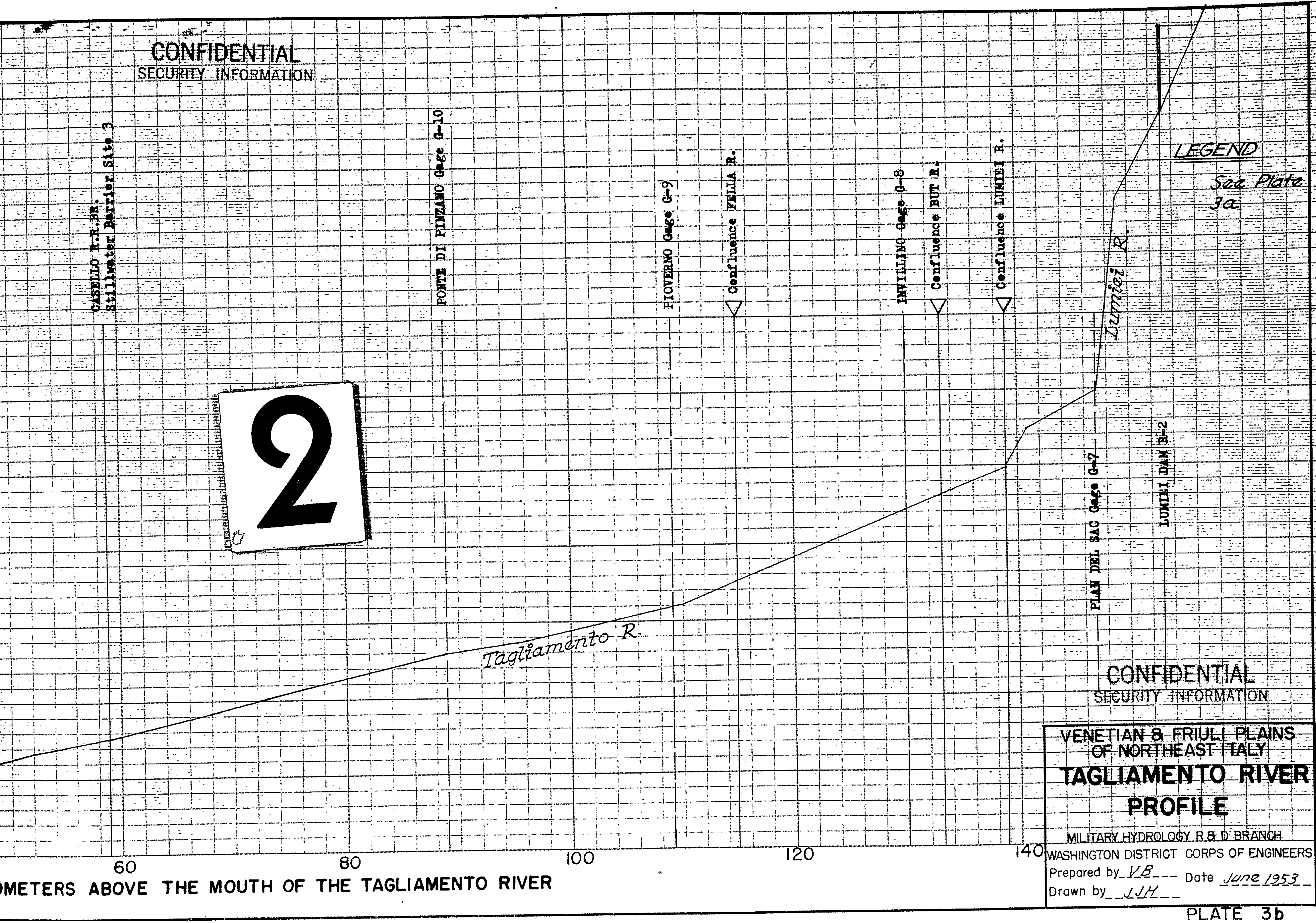
SECURITY INFORMATION
LATISANA R.R.BR.
Stillwater Barrier Site 2
Gage G-13
FRAFOREANO Gage G-12
PASSO CAMUSSIO Gage G-11
CASELLO R.R.BR.
Stillwater Barrier Site 3
PONTE DI PINZANO Gage G-10
Tagliamento R.
ELEVATION IN METERS above M.S.L.
1000
800
600
400
200
0
0
20
40
60
80
100
KILOMETERS ABOVE THE MOUTH OF THE TAGLIAMENTO RIVER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SECURITY INFORMATION
CASELLO R.R.BR.
Stillwater Barrier Site 3
PONTE DI PINZANO Gage G-10
PIOVERNO Gage G-9
Confluence FELLA R.
INVILLINO Gage G-8
Confluence BUT R.
Confluence LUMIEI R.
PLAN DEL SAC Gage G-7
LUMIEI DAM R-2
LEGEND
See Plate 3a
Lumiei R.
Tagliamento R.
2
60
80
100
120
140
OMETERS ABOVE THE MOUTH OF THE TAGLIAMENTO RIVER
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VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY
TAGLIAMENTO RIVER PROFILE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by V.B. Date June 1953
Drawn by J.J.H.
PLATE 3b

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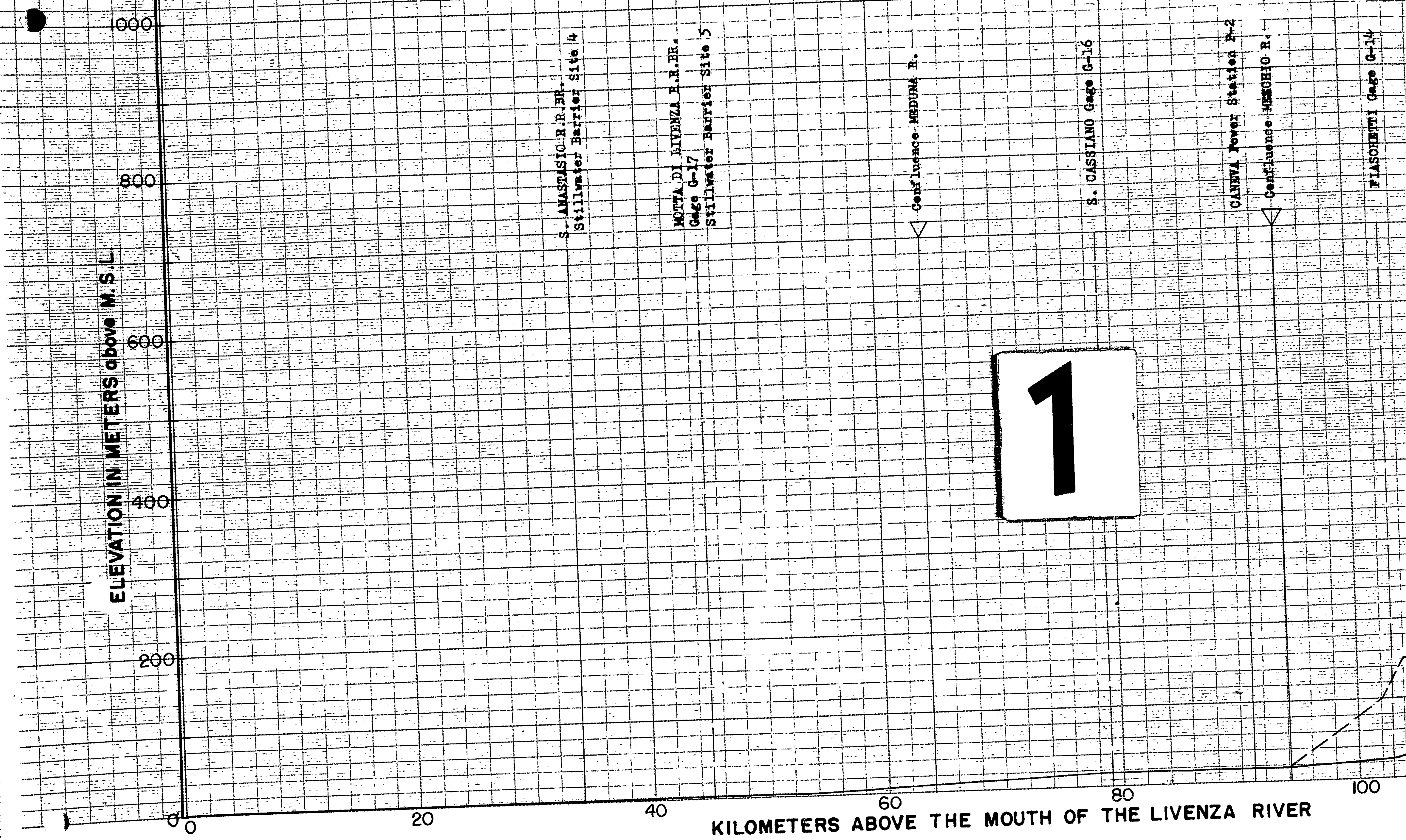

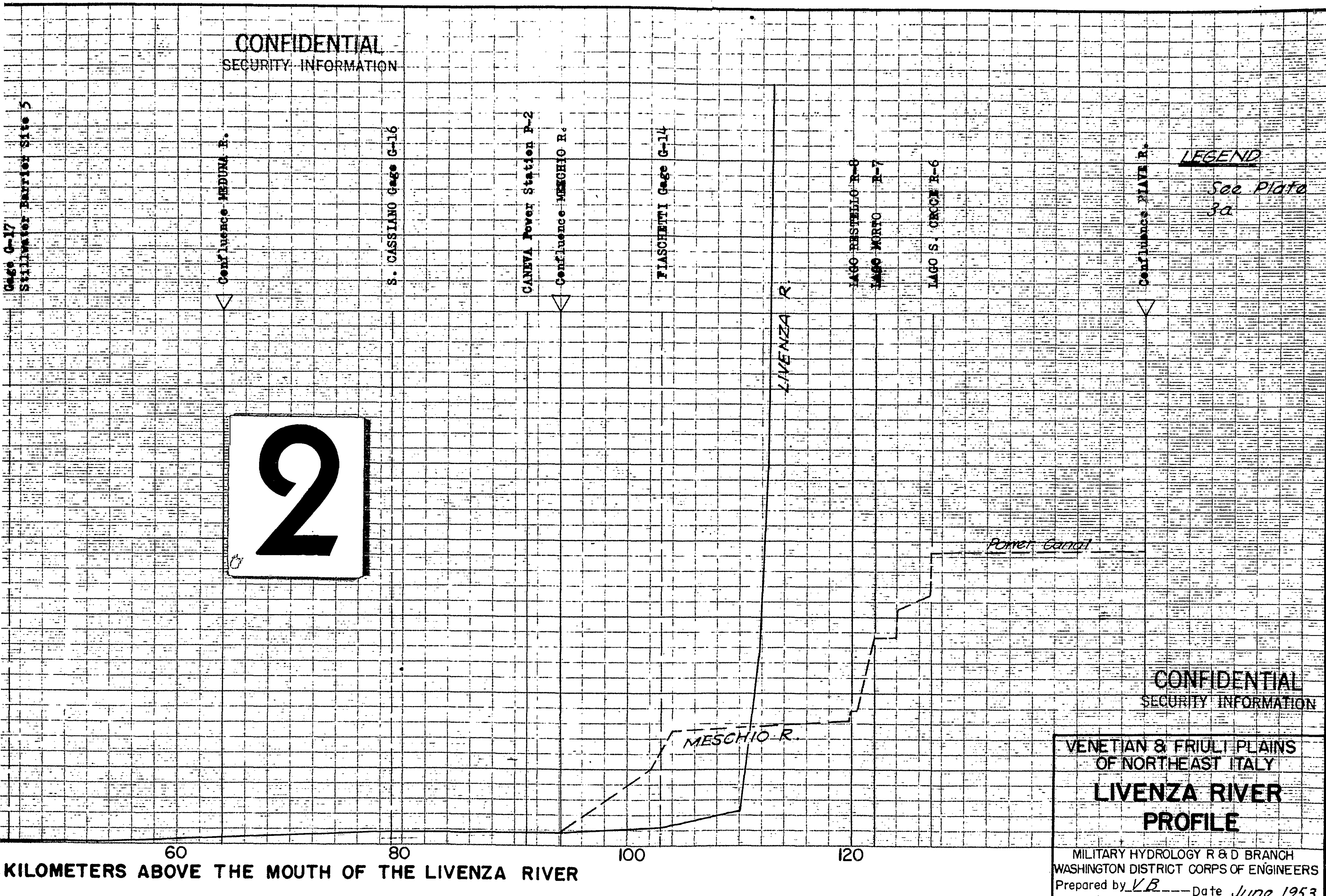

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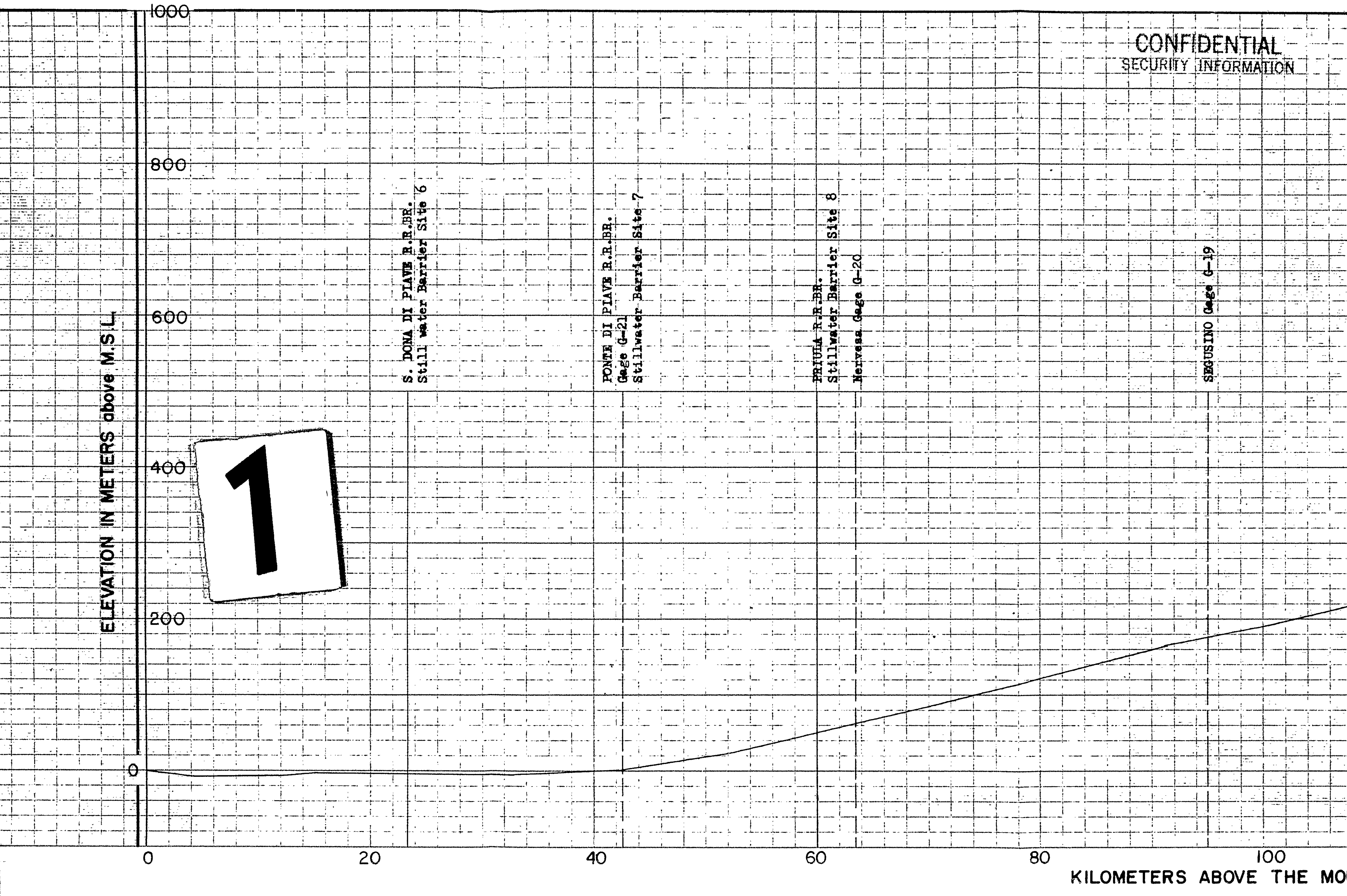
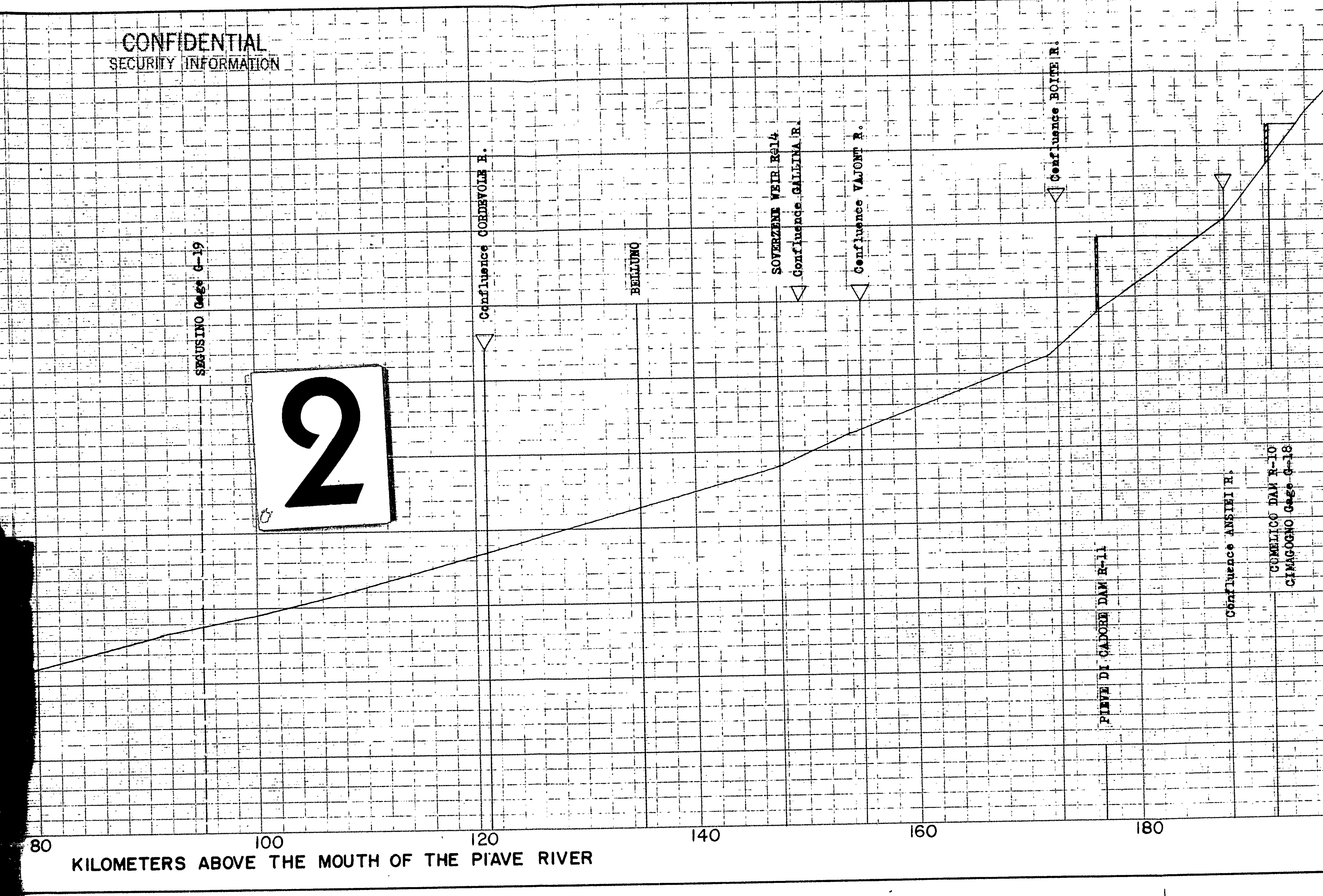
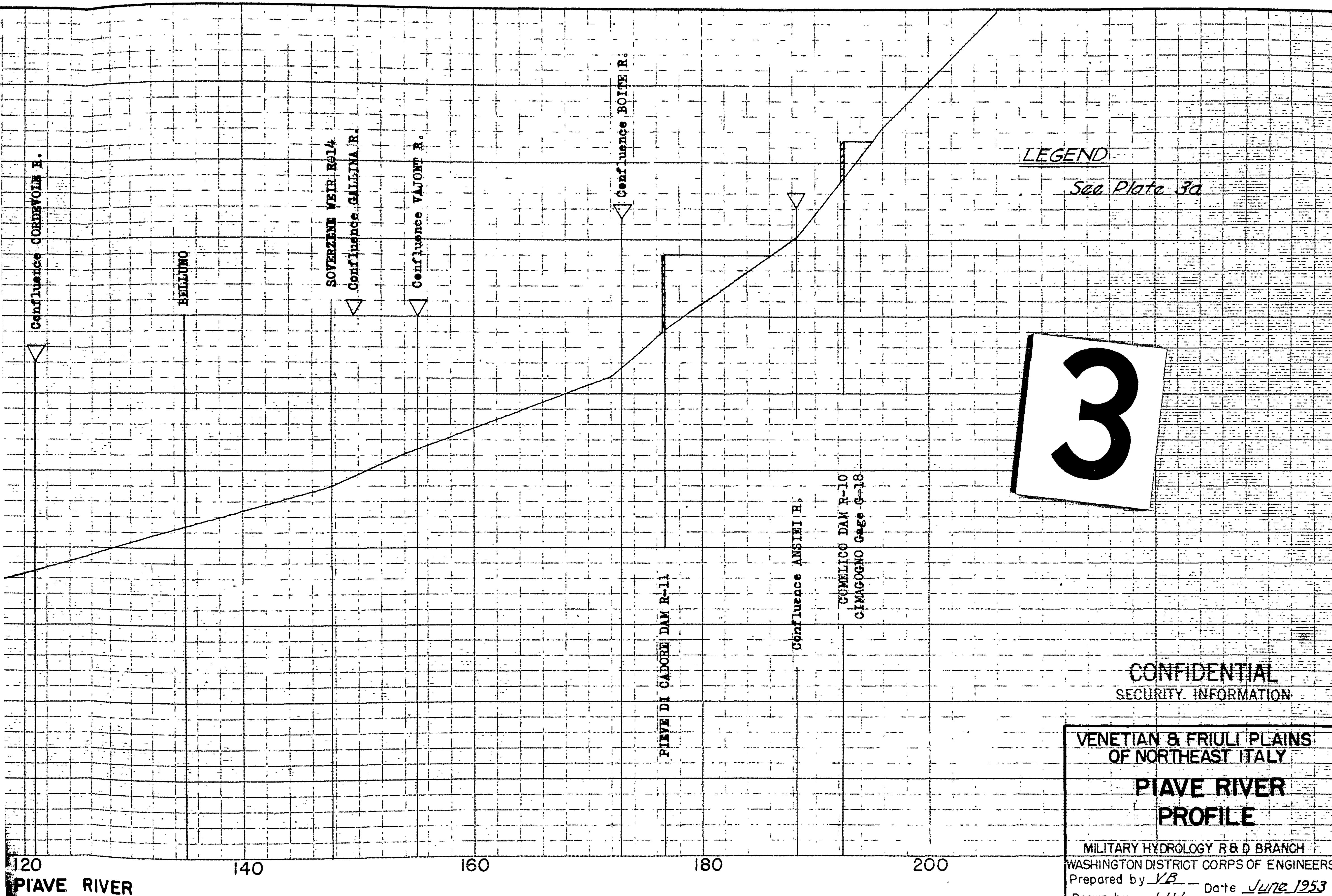
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

LIVENZA RIVER PROFILE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date June 1953
Drawn by JJH


ELEVATION IN METERS above M.S.L.
1000
800
600
400
200
0
S. DONA DI PIAVE R.R.BR.
Still water Barrier Site 6
PONTE DI PIAVE R.R.BR.
Gage G-21
Stillwater Barrier Site 7
PRIULA R.R.BR.
Stillwater Barrier Site 8
Nervesa Gage G-20
SEGUSINO Gage G-19
1
0
20
40
60
80
100
KILOMETERS ABOVE THE MO


CONFIDENTIAL
SECURITY INFORMATION
2
SEGUSINO Gage G-19
Confluence CORDEVOLE R.
BELLUNO
SOVERZENE WEIR R-14
Confluence GALLINA R.
Confluence VAJONT R.
Confluence BOITE R.
PIEVE DI CADORE DAM R-11
Confluence ANSIEI R.
COMELICO DAM R-10
CIMAGOGNO Gage G-18
80
100
120
140
160
180
KILOMETERS ABOVE THE MOUTH OF THE PIAVE RIVER



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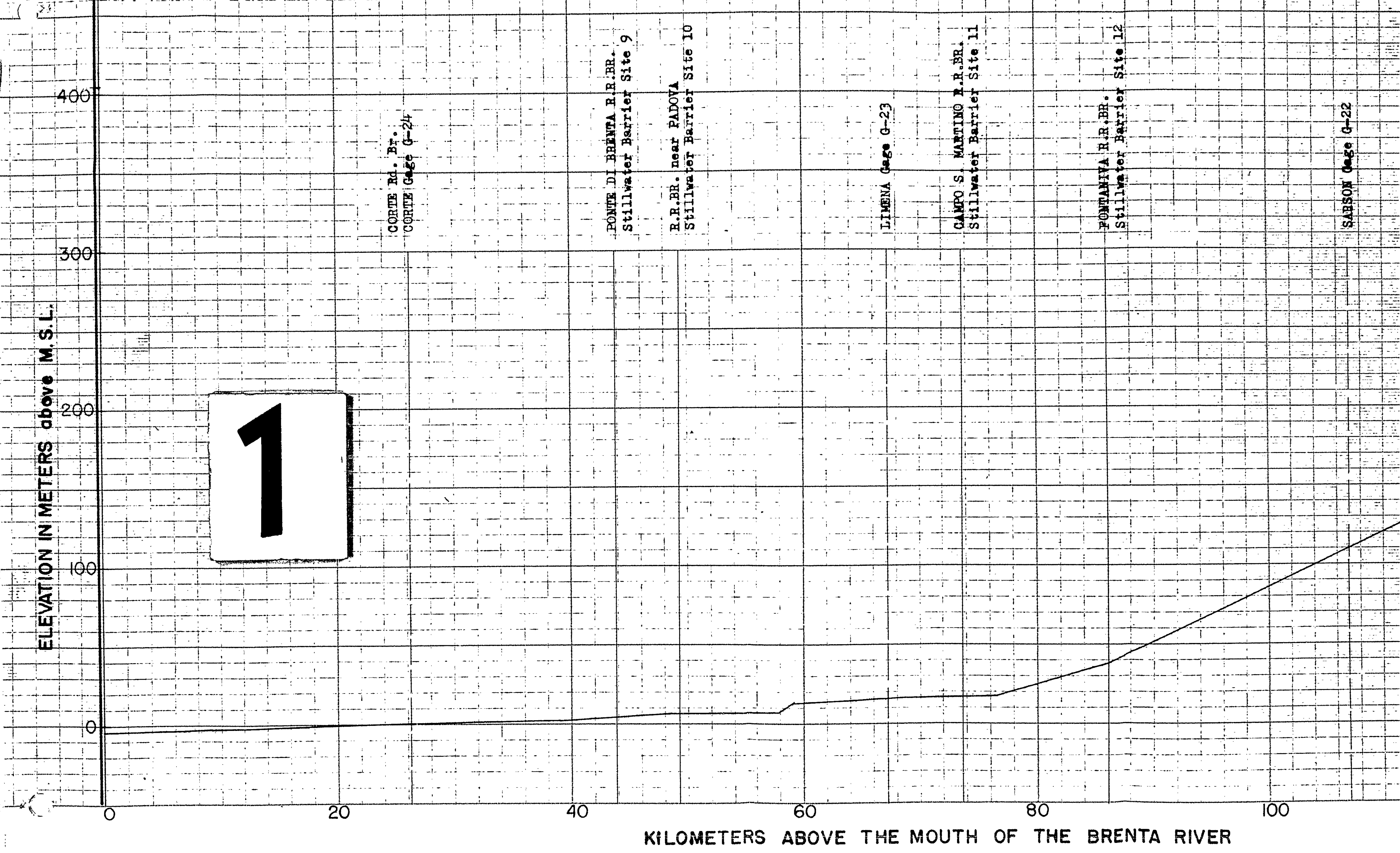
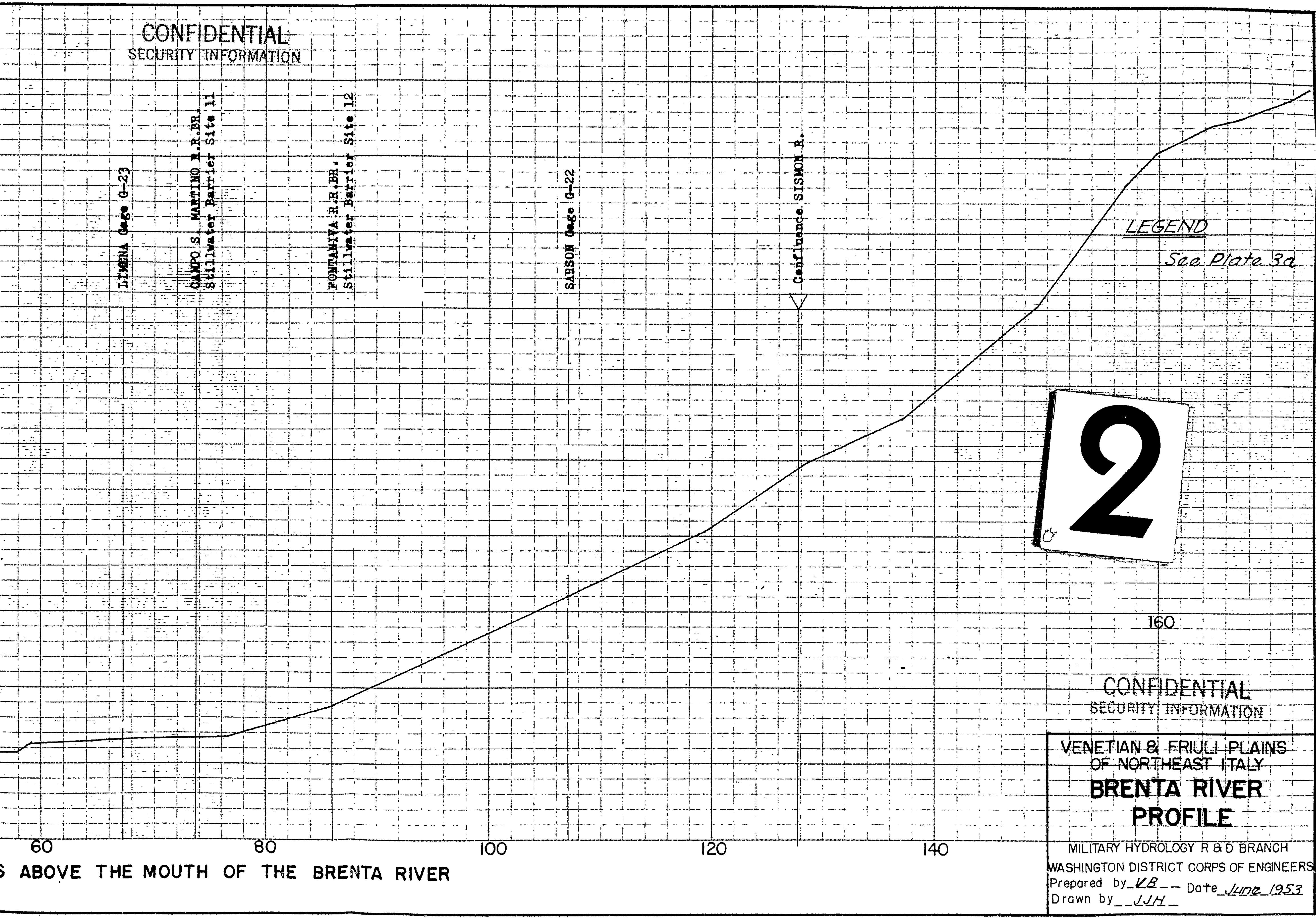
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

PIAVE RIVER PROFILE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB Date June 1953
Drawn by JJH

PLATE 3d


CORTE Rd. Br.
CORTE Gage G-24
PONTE DI BRENTA R.R.BR.
Stillwater Barrier Site 9
R.R.BR. near PADOVA
Stillwater Barrier Site 10
LIMENA Gage G-23
CAMPO S. MARTINO R.R.BR.
Stillwater Barrier Site 11
FONTANIVA R.R.BR.
Stillwater Barrier Site 12
SABSON Gage G-22
500
400
300
200
100
0
ELEVATION IN METERS above M.S.L.
0
20
40
60
80
100
KILOMETERS ABOVE THE MOUTH OF THE BRENTA RIVER
1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SECURITY INFORMATION
LIMENA Gage G-23
CAMPO S. MARTINO R.R.BR.
Stillwater Barrier Site 11
FONTANIVA R.R.BR.
Stillwater Barrier Site 12
SARSON Gage G-22
Confluence SISMON R.
LEGEND
See Plate 3a
2
60
80
100
120
140
160
S ABOVE THE MOUTH OF THE BRENTA RIVER
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SECURITY INFORMATION
VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY
BRENTA RIVER
PROFILE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
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PLATE 3e

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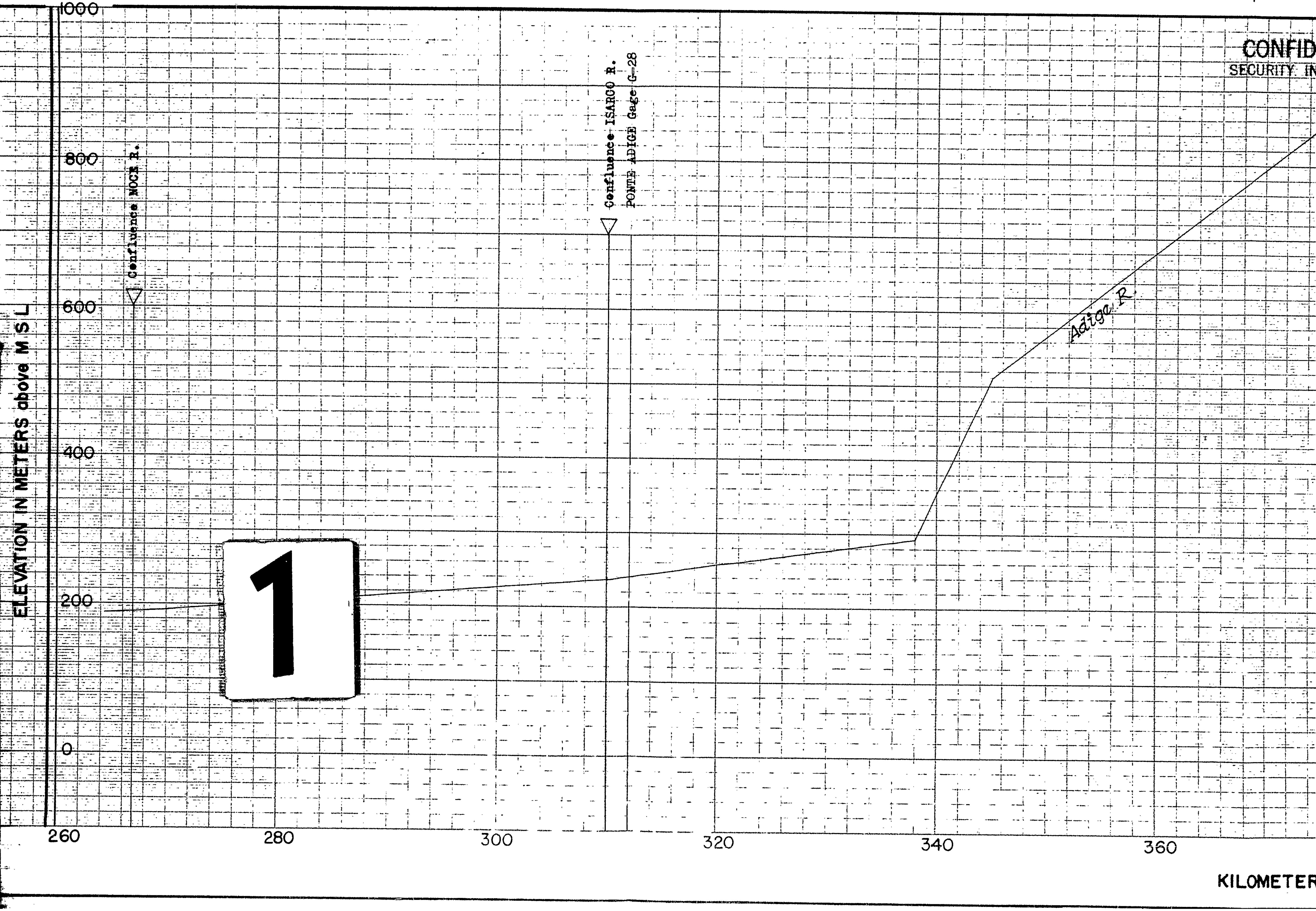
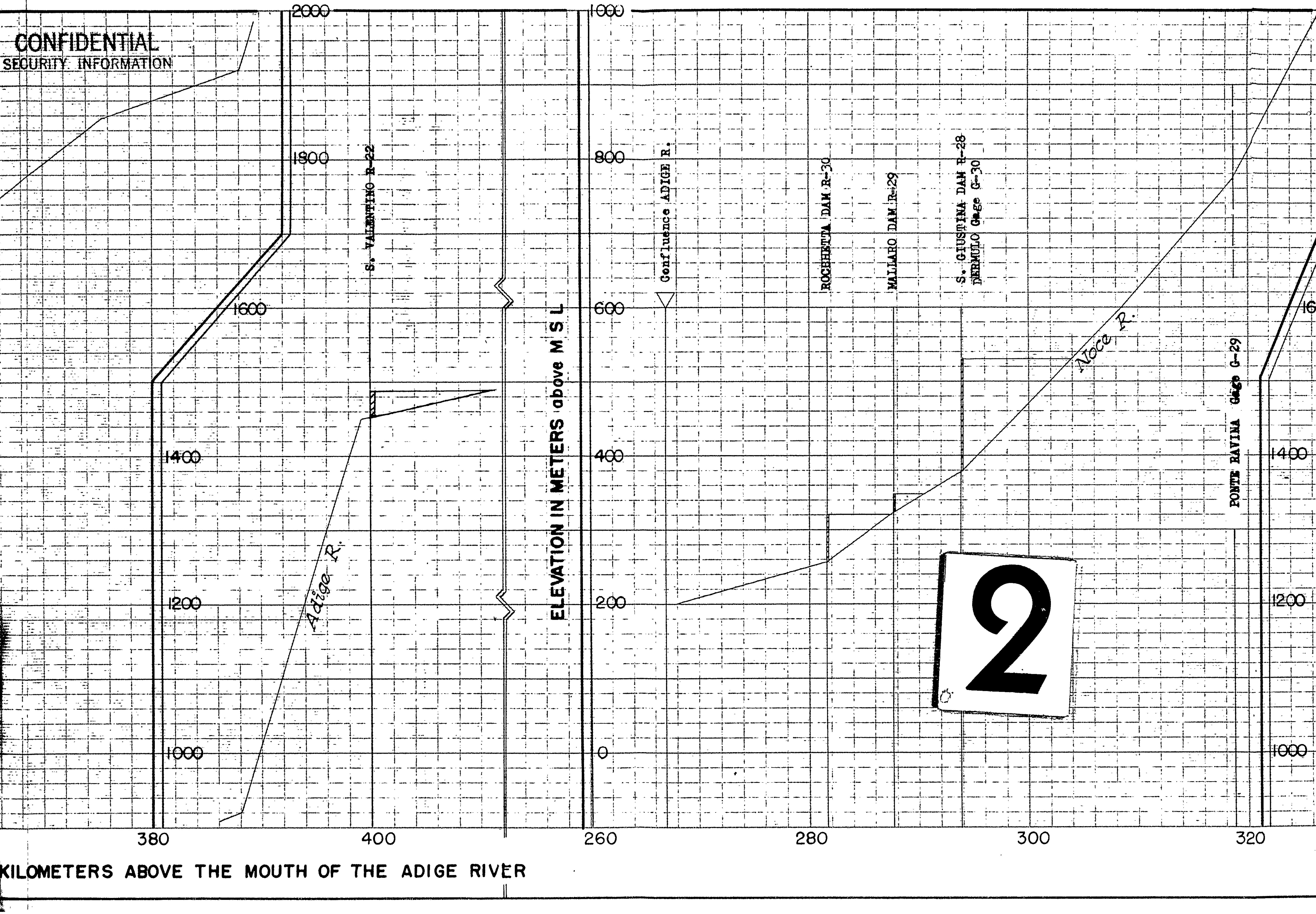
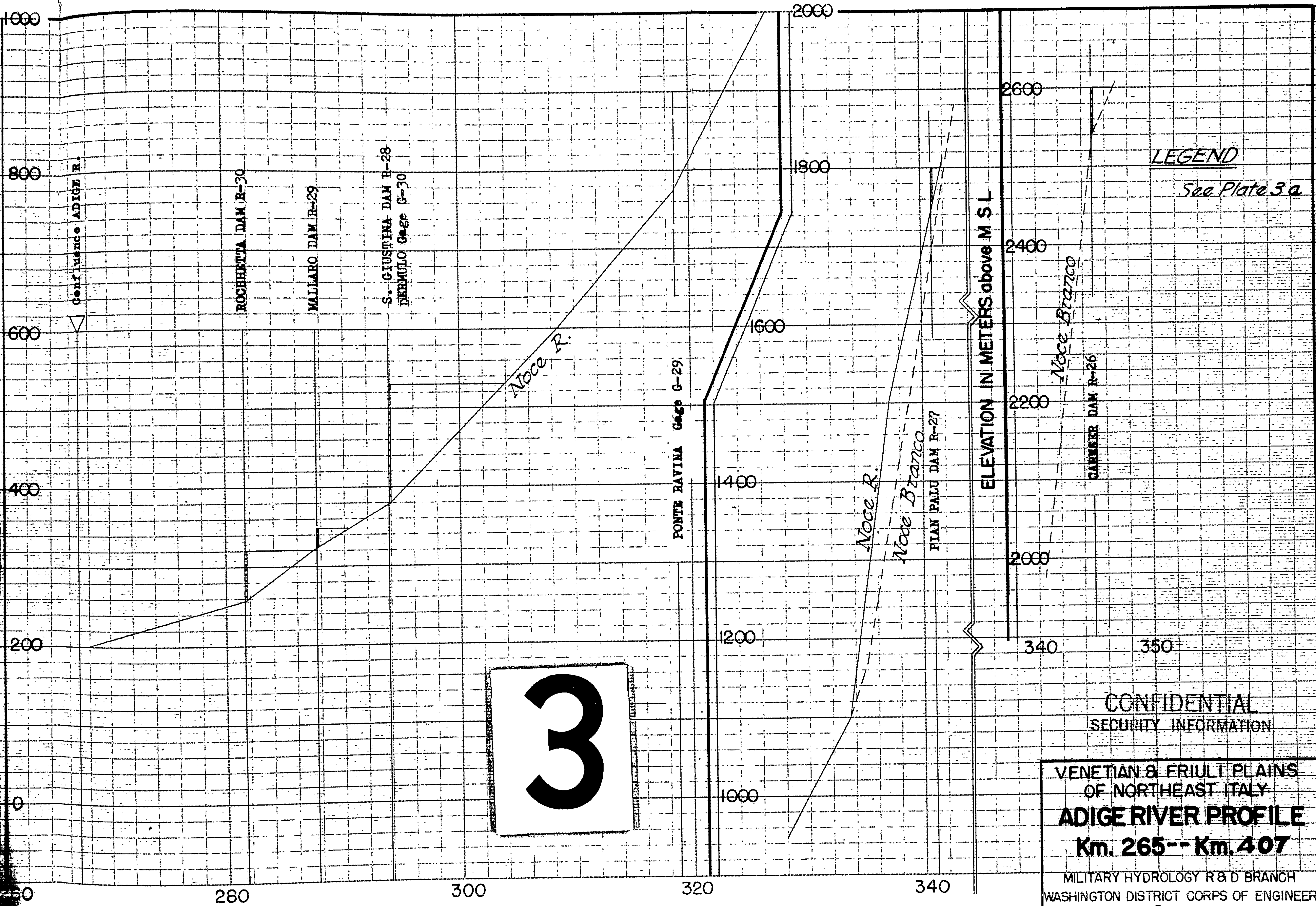



2000
1800
1600
1400
1200
1000
S. VALENTINO R-22
Adige R.
ELEVATION IN METERS above M S L
1000
800
600
400
200
0
Confluence ADIGE R.
ROCHETTA DAM R-30
MALLARO DAM R-29
S. GIUSTINA DAM R-28
DERMULO Gage G-30
Noce R.
PONTE RAVINA Gage G-29
1400
1200
1000
380
400
260
280
300
320
KILOMETERS ABOVE THE MOUTH OF THE ADIGE RIVER
2



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SECURITY INFORMATION

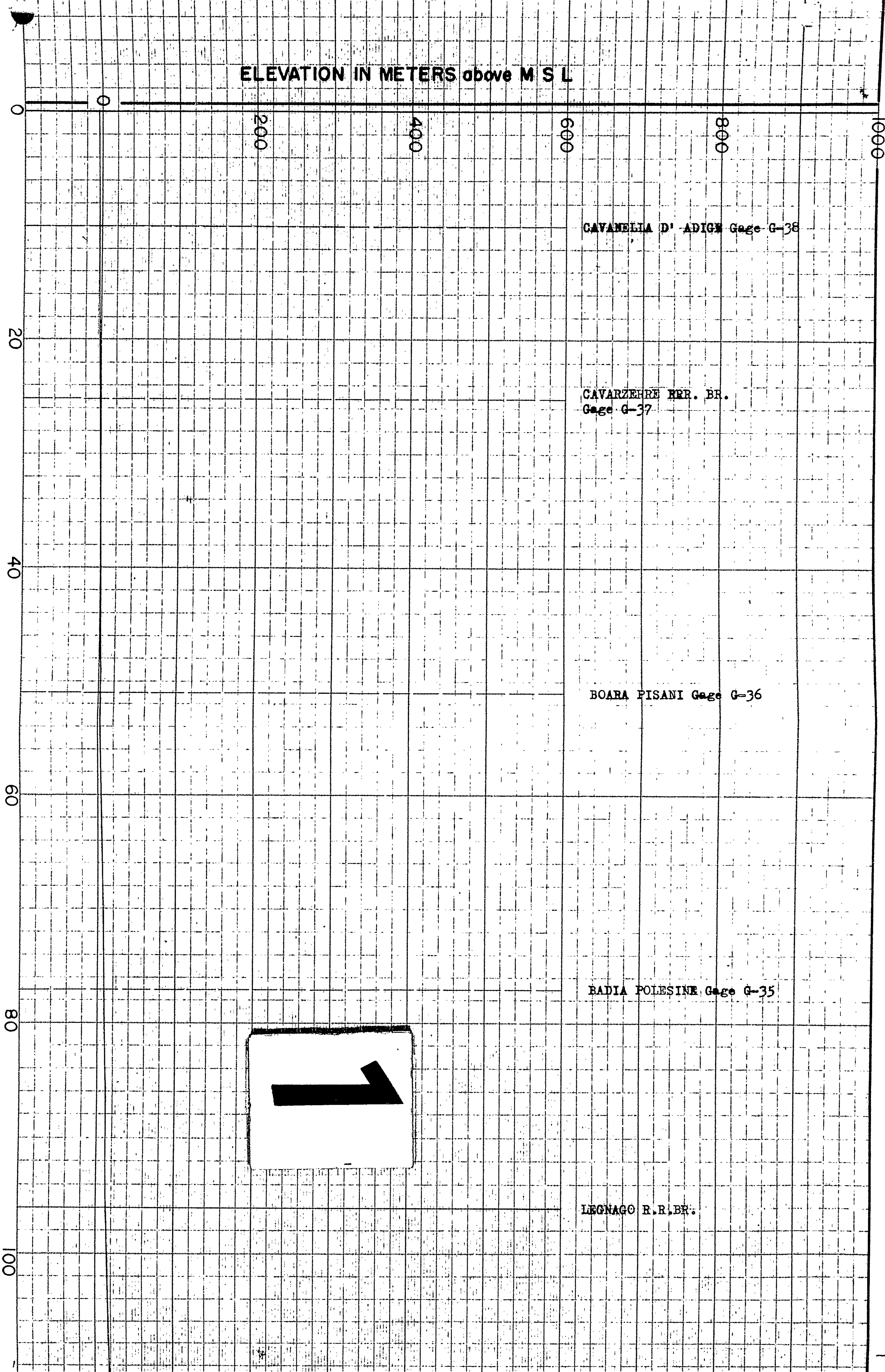
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

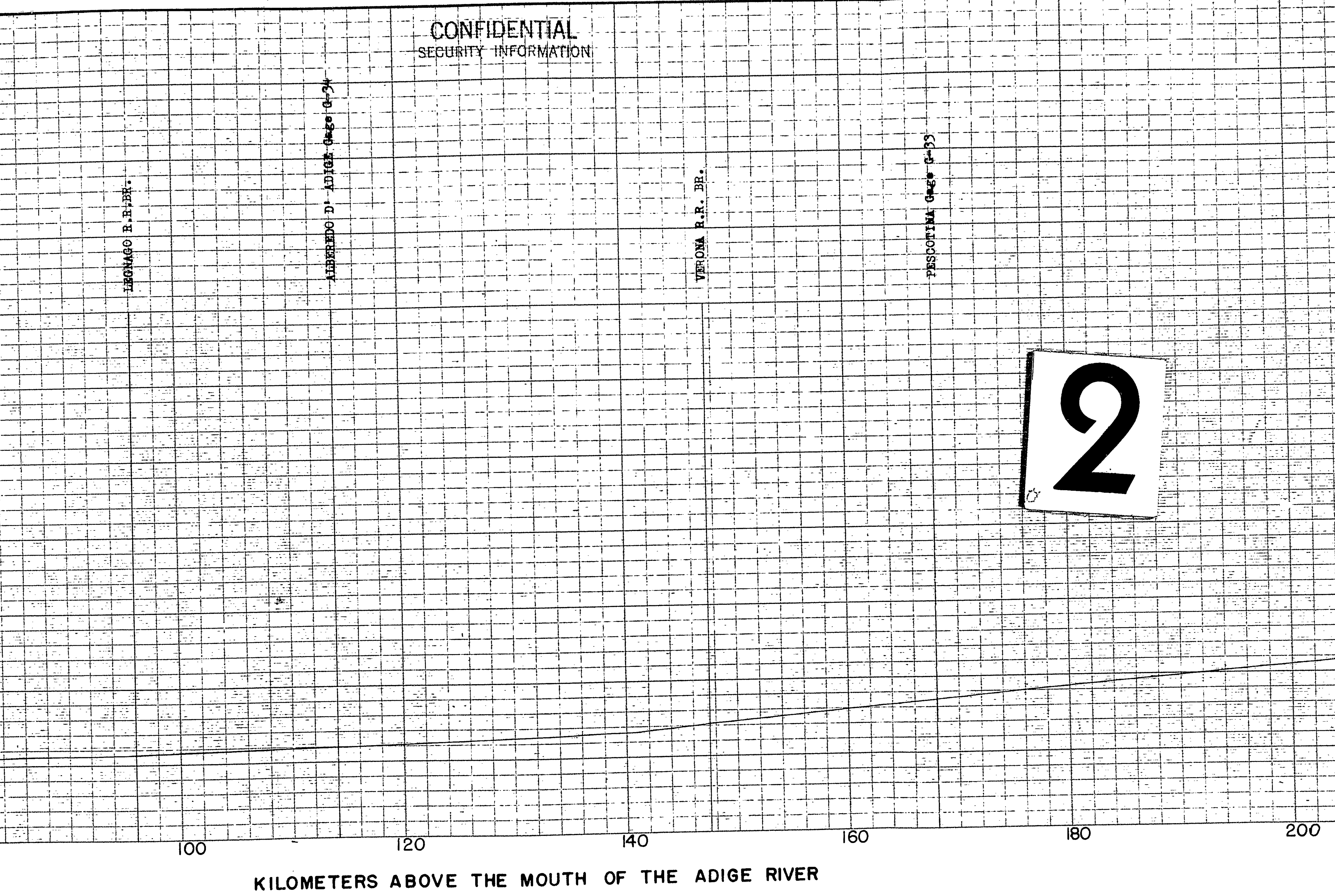
ADIGE RIVER PROFILE

Km. 265--Km. 407

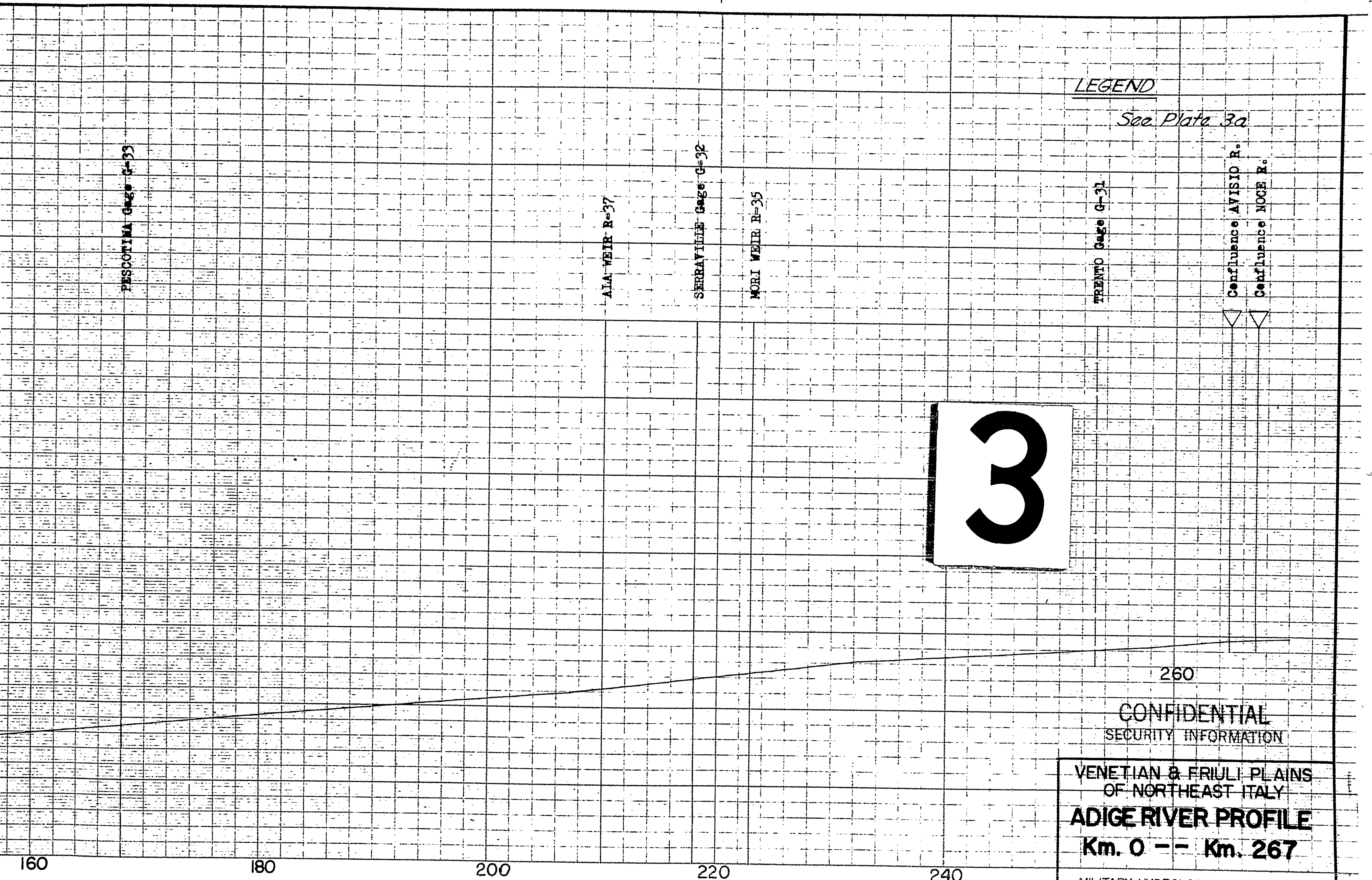
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by V.B. Date June 1953
Drawn by JJH

PLATE 3f


ELEVATION IN METERS above M S L
0
200
400
600
800
1000
CAVANELLA D' ADIGE Gage G-38
CAVARZERE RRR. BR.
Gage G-37
BOARA PISANI Gage G-36
BADIA POLESINE Gage G-35
LEGNAGO R.R.BR.
20
40
60
80
100



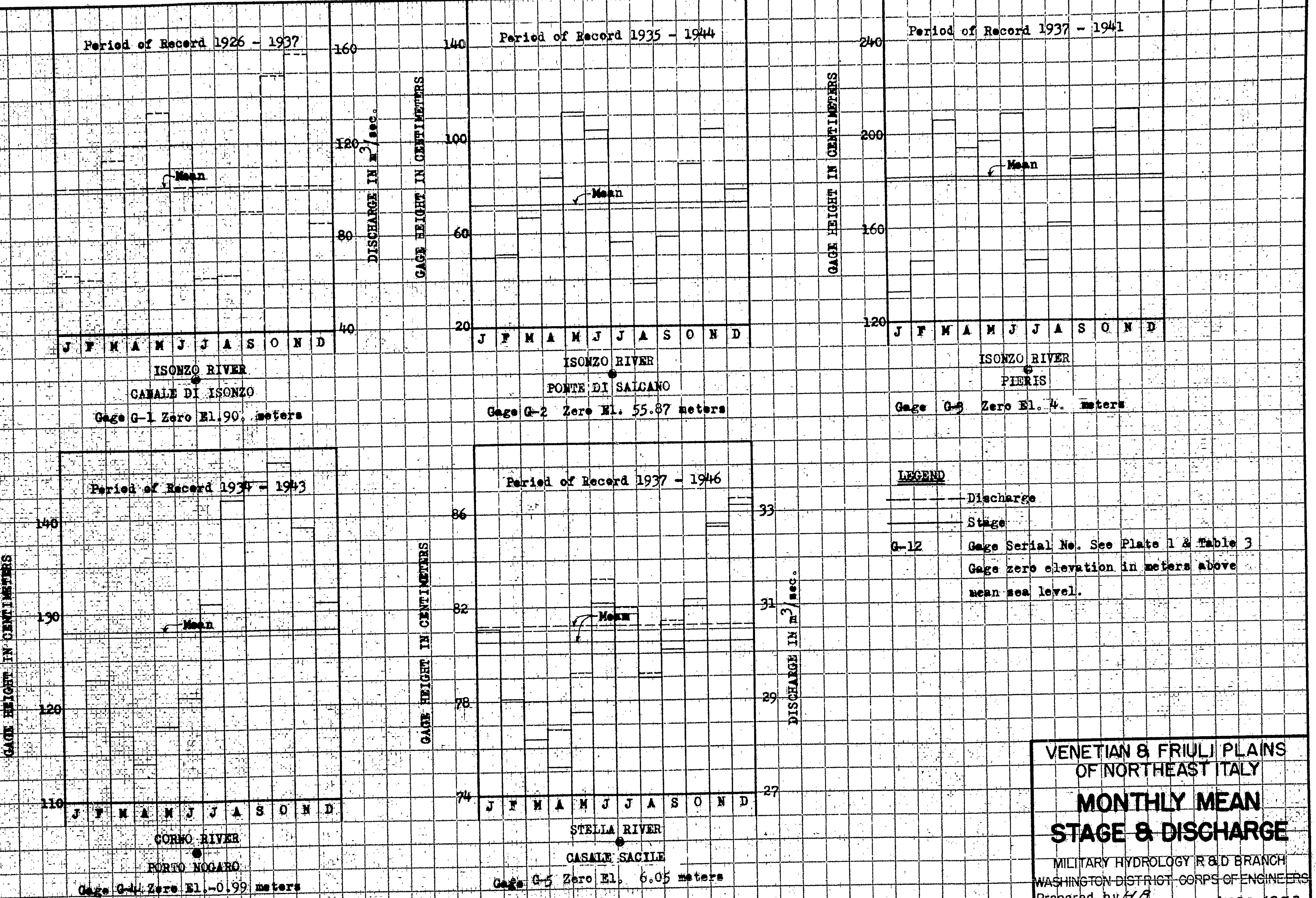
CONFIDENTIAL
SECURITY INFORMATION
LEGNAGO R.R.BR.
ALBEREDO D' ADIGE Gage G-34
VERONA R.R. BR.
PESCOTINA Gage G-33
2
100
120
140
160
180
200
KILOMETERS ABOVE THE MOUTH OF THE ADIGE RIVER



CONFIDENTIAL
SECURITY INFORMATION

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY
ADIGE RIVER PROFILE
Km. 0 -- Km. 267

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB
Drawn by JJH
Date June 1953



VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

MONTHLY MEAN
STAGE & DISCHARGE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by H.B. Date June 1953
Drawn by J.J.H.

PLATE 4a

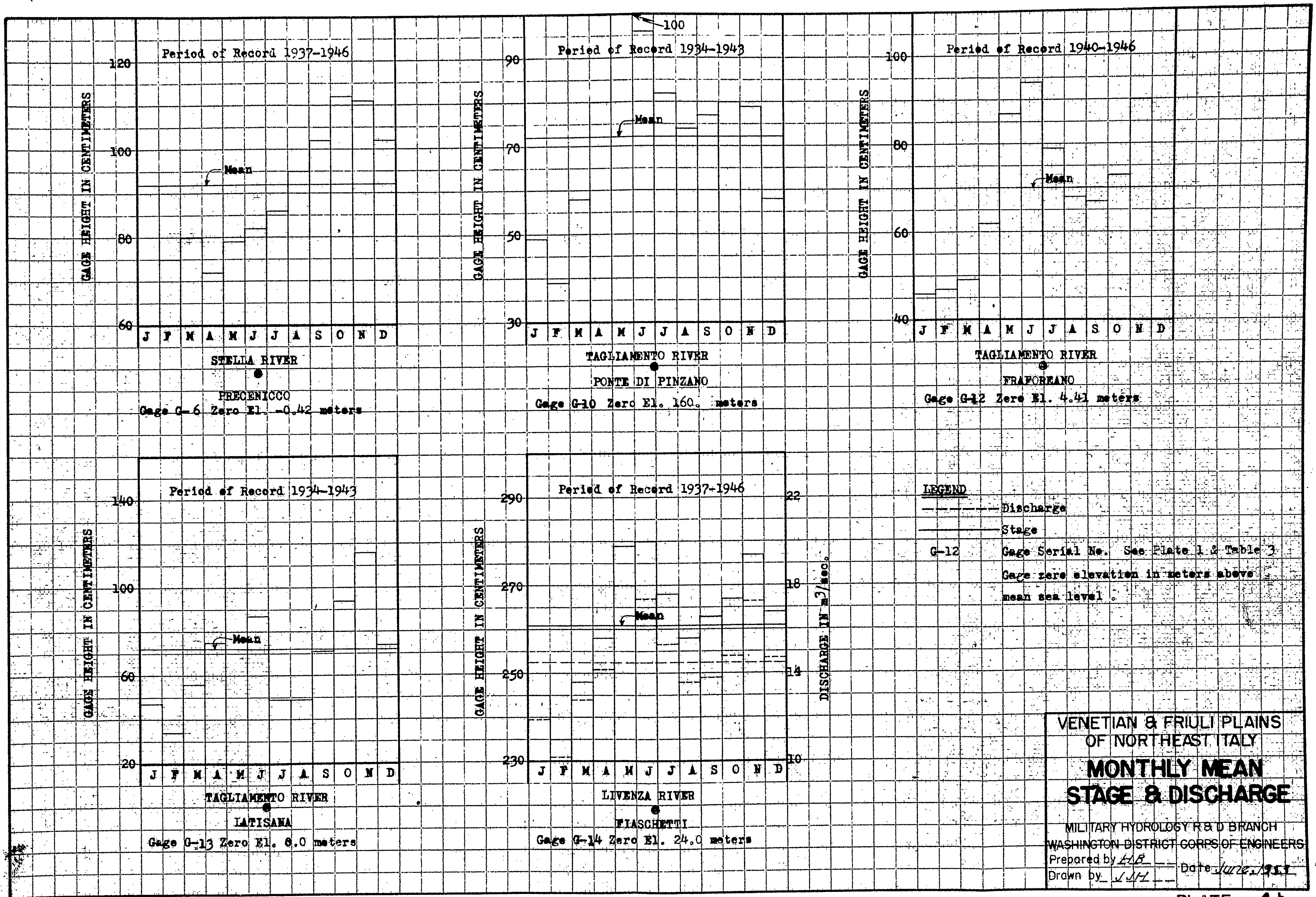
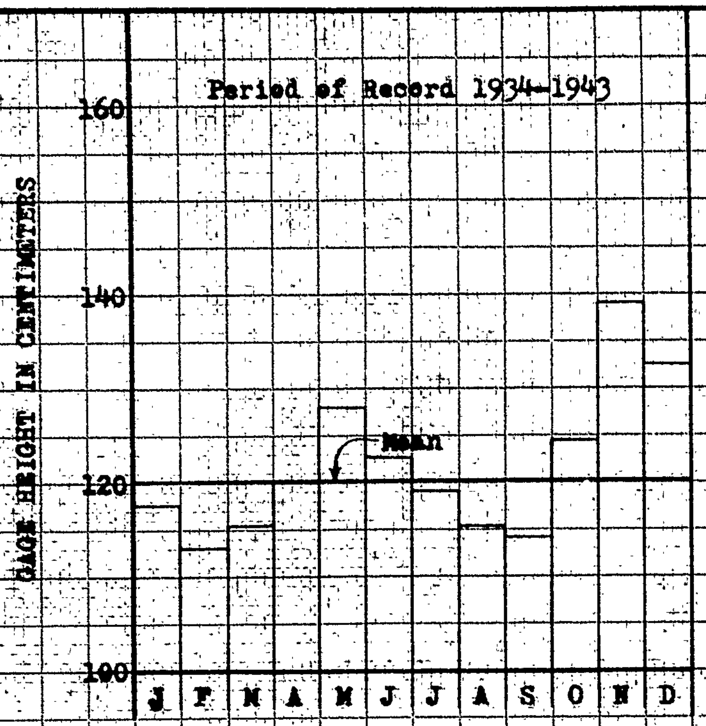
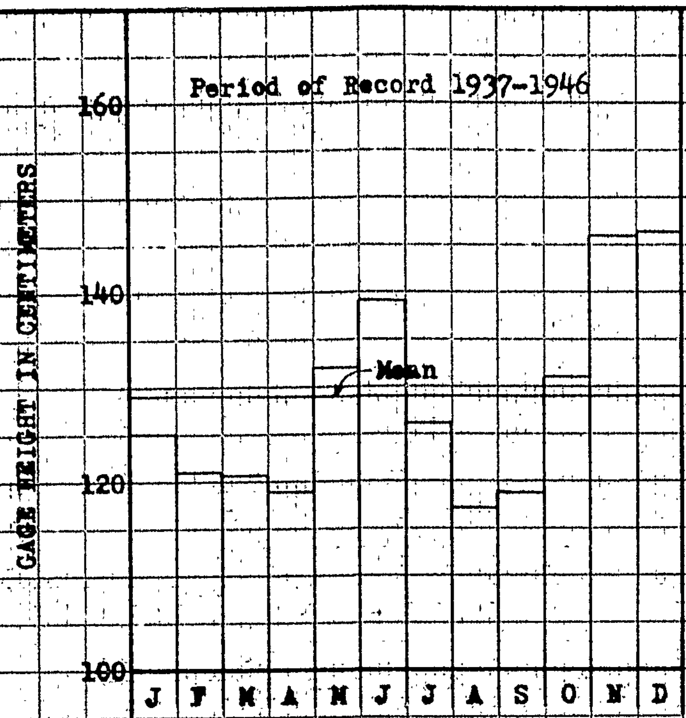

Period of Record 1937-1946
GAGE HEIGHT IN CENTIMETERS
Mean
J F M A M J J A S O N D
STELLA RIVER
PRECENICCO
Gage G-6 Zero El. -0.42 meters
Period of Record 1934-1943
100
Mean
J F M A M J J A S O N D
TAGLIAMENTO RIVER
PONTE DI PINZANO
Gage G-10 Zero El. 160. meters
Period of Record 1940-1946
Mean
J F M A M J J A S O N D
TAGLIAMENTO RIVER
FRAFORKANO
Gage G-12 Zero El. 4.41 meters
Period of Record 1934-1943
Mean
J F M A M J J A S O N D
TAGLIAMENTO RIVER
LATISANA
Gage G-13 Zero El. 6.0 meters
Period of Record 1937-1946
DISCHARGE IN m3/sec.
Mean
J F M A M J J A S O N D
LIVENZA RIVER
FIASCHETTI
Gage G-14 Zero El. 24.0 meters
LEGEND
Discharge
Stage
G-12 Gage Serial No. See Plate 1 & Table 3
Gage zero elevation in meters above mean sea level.
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY
MONTHLY MEAN STAGE & DISCHARGE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HB
Drawn by JJH
Date June, 1951

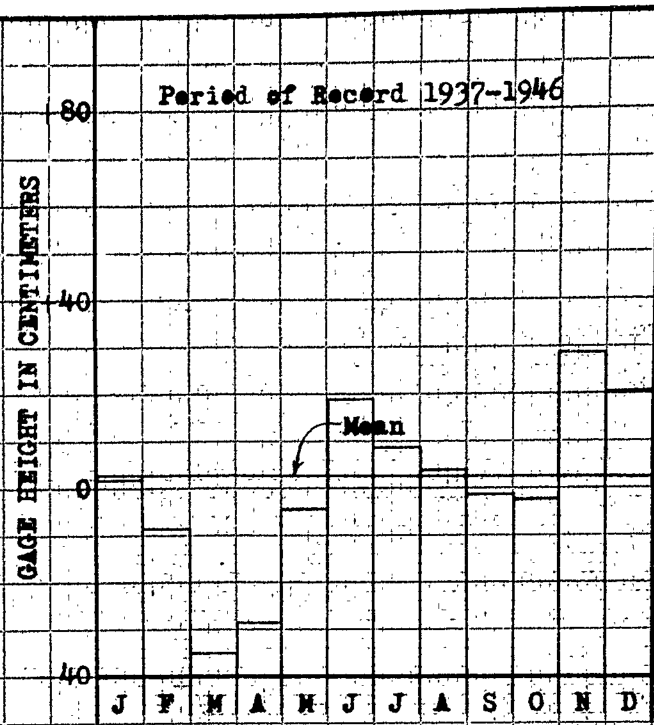
PLATE 4 b



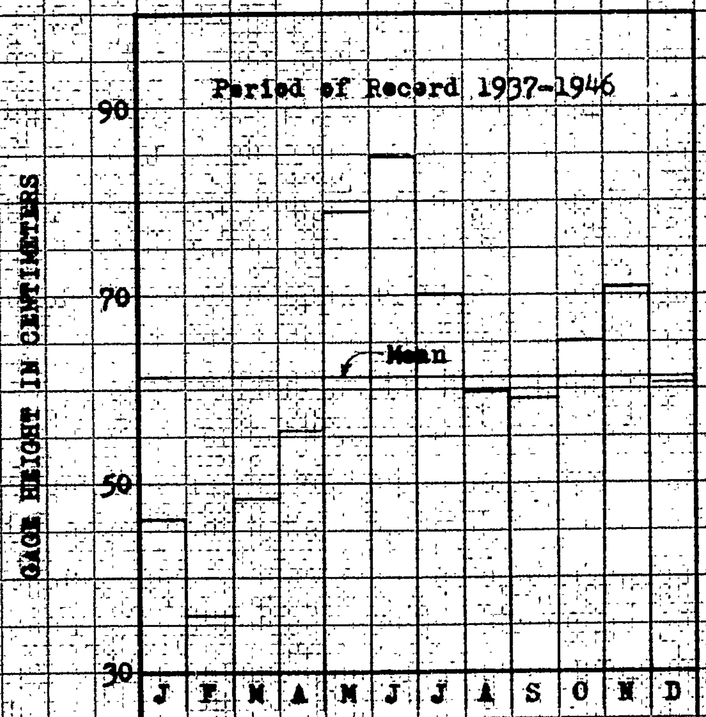
MEDUNA RIVER
@
PONTE MEDUNA
Gage G-15 Zero El. 14.43 meters



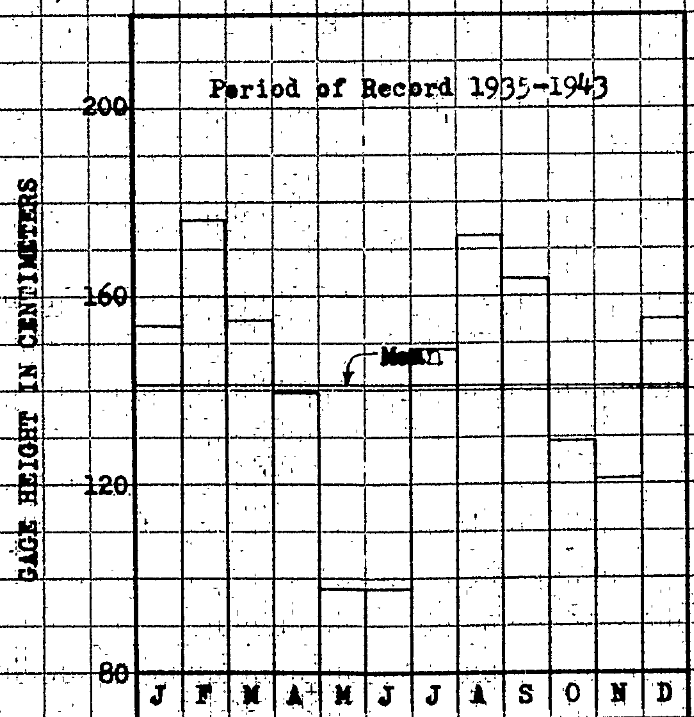
LIVENZA RIVER
@
S. CASSIANO
Gage G-16 Zero El. 6.07 meters



LIVENZA RIVER
@
MOTTA DI LIVENZA
Gage G-17 Zero El. 2.14 meters



PIAVE RIVER
@
NERVESA
Gage G-20 Zero El. 77.54 meters



PIAVE RIVER
@
PONTE DI PIAVE
Gage G-21 Zero El. 6.21 meters

LEGEND

---------- Discharge

———— Stage

G-12 Gage Serial No. See Plate 1 & Table 3

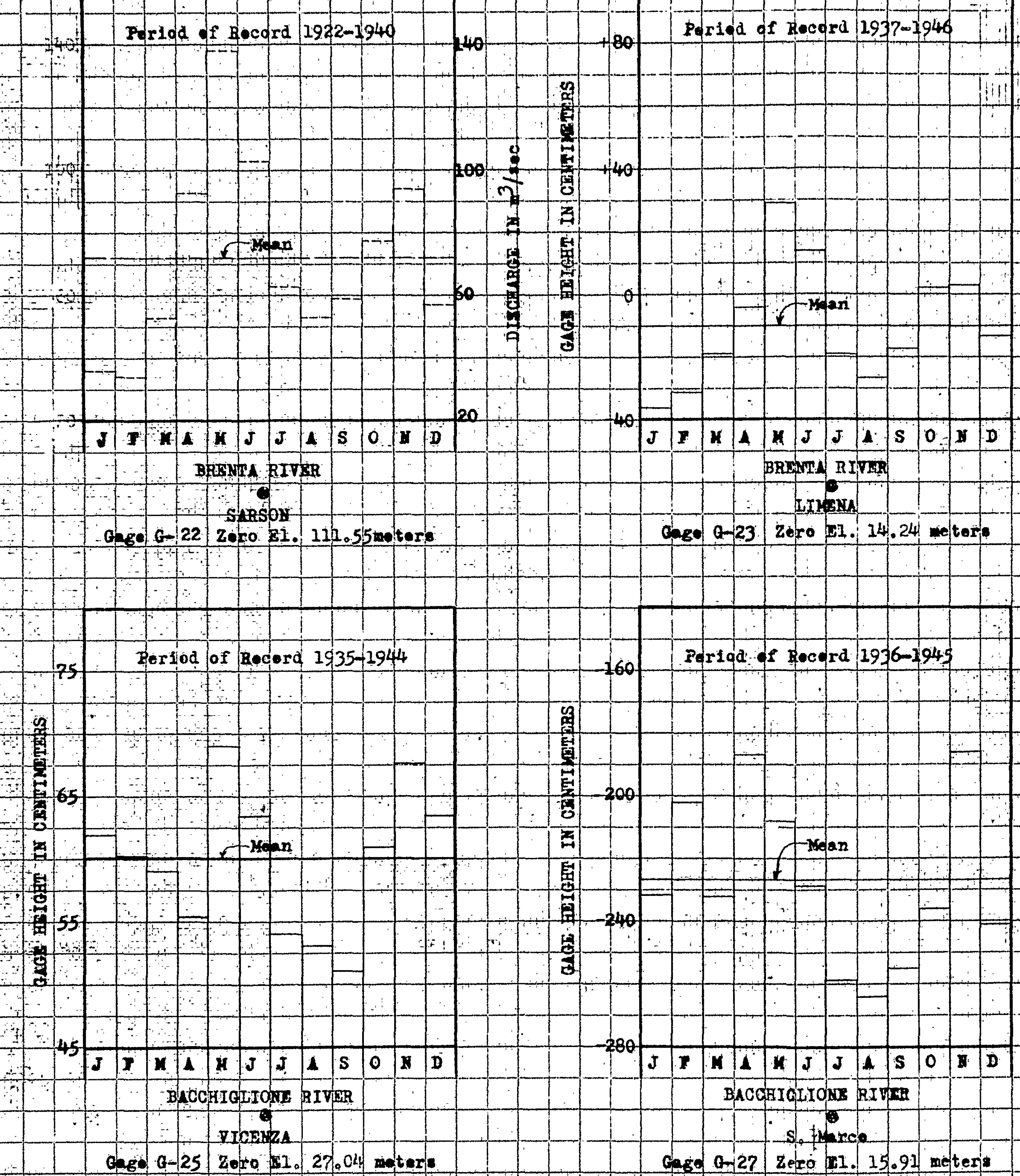
Gage Zero elevation in meters above mean sea level.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

MONTHLY MEAN STAGE & DISCHARGE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by W.B.
Drawn by J.J.H. Date June 1953

PLATE 4c



LEGEND

- - - - - Discharge

——— Stage

G-12 Gage Serial No. See Plate 1 & Table 3

Gage zero elevation in meters above mean sea level.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

MONTHLY MEAN STAGE & DISCHARGE

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by H.B. Date June 1953
Drawn by J.J.H.

PLATE 4 d

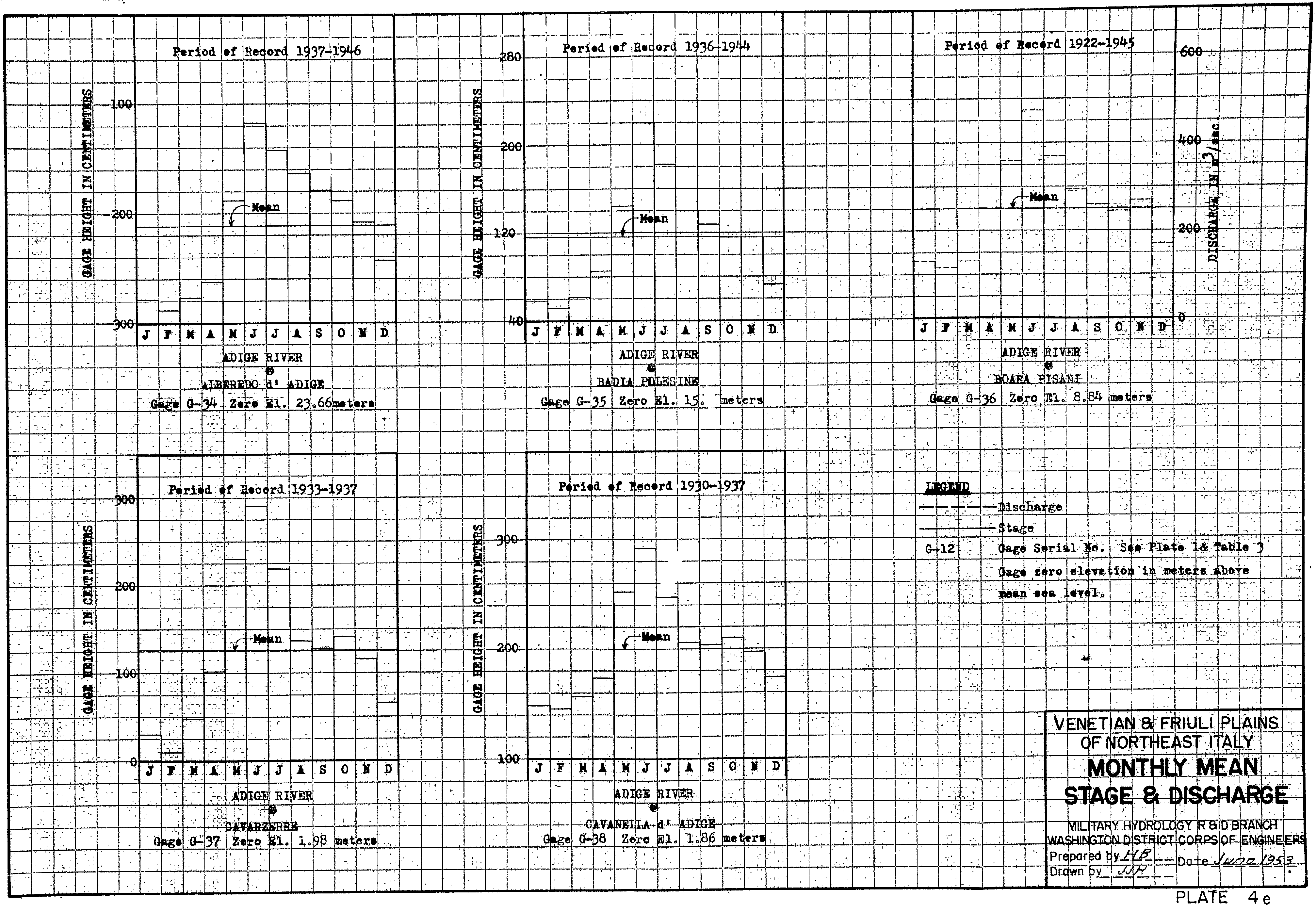

Period of Record 1937-1946
GAGE HEIGHT IN CENTIMETERS
100
200
300
Mean
J F M A M J J A S O N D
ADIGE RIVER
@
ALBEREDO d' ADIGE
Gage G-34 Zero El. 23.66 meters
Period of Record 1936-1944
GAGE HEIGHT IN CENTIMETERS
280
200
120
40
Mean
J F M A M J J A S O N D
ADIGE RIVER
@
BADIA POLESINE
Gage G-35 Zero El. 15. meters
Period of Record 1922-1945
DISCHARGE IN m3/sec
600
400
200
0
Mean
J F M A M J J A S O N D
ADIGE RIVER
@
BOARA PISANI
Gage G-36 Zero El. 8.84 meters
Period of Record 1933-1937
GAGE HEIGHT IN CENTIMETERS
300
200
100
0
Mean
J F M A M J J A S O N D
ADIGE RIVER
@
CAVARZERE
Gage G-37 Zero El. 1.98 meters
Period of Record 1930-1937
GAGE HEIGHT IN CENTIMETERS
300
200
100
Mean
J F M A M J J A S O N D
ADIGE RIVER
@
CAVANELLA d' ADIGE
Gage G-38 Zero El. 1.86 meters
LEGEND
Discharge
Stage
G-12 Gage Serial No. See Plate 1 & Table 3
Gage zero elevation in meters above mean sea level.
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY
MONTHLY MEAN
STAGE & DISCHARGE
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HB Date June 1953
Drawn by JJH

PLATE 4e

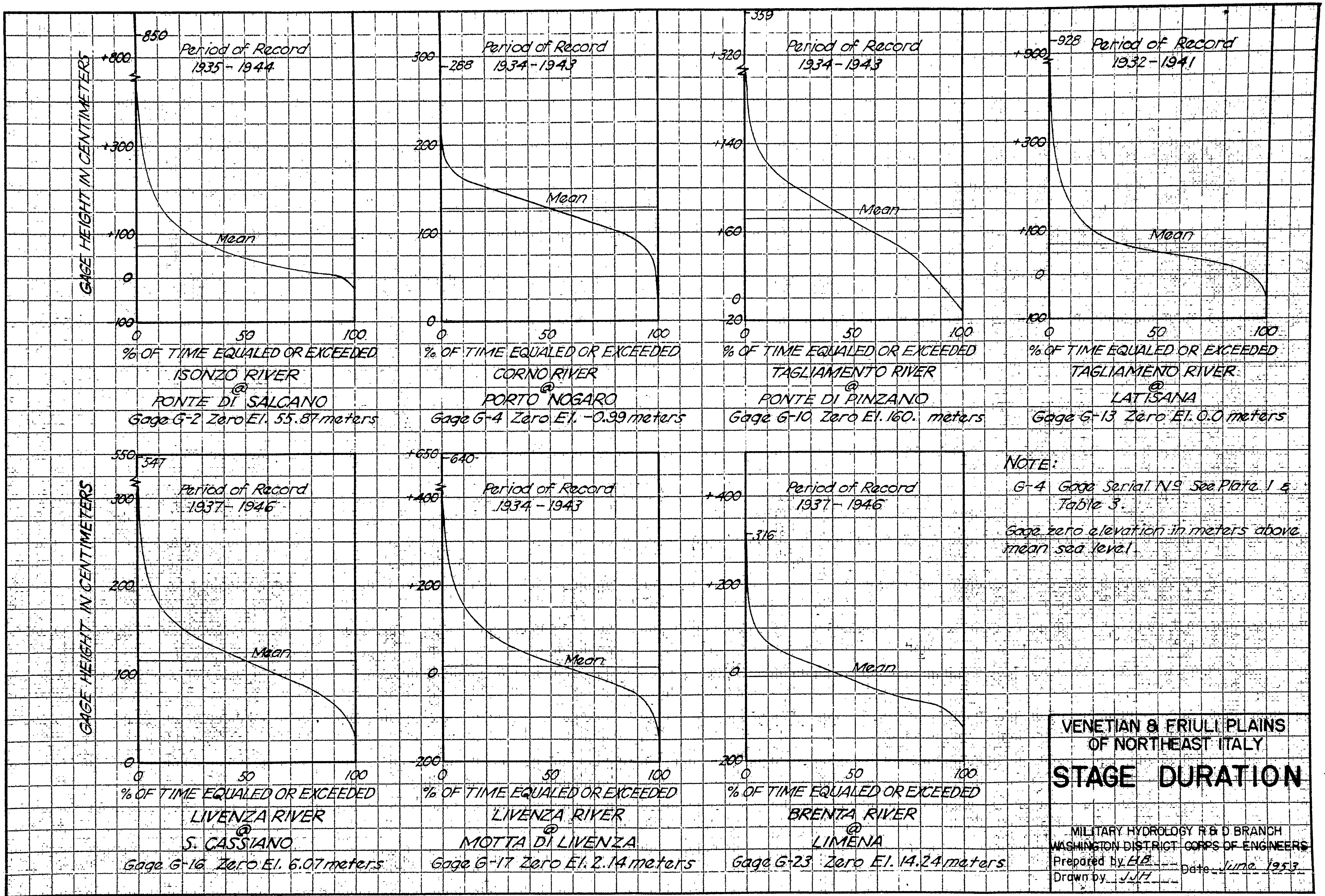
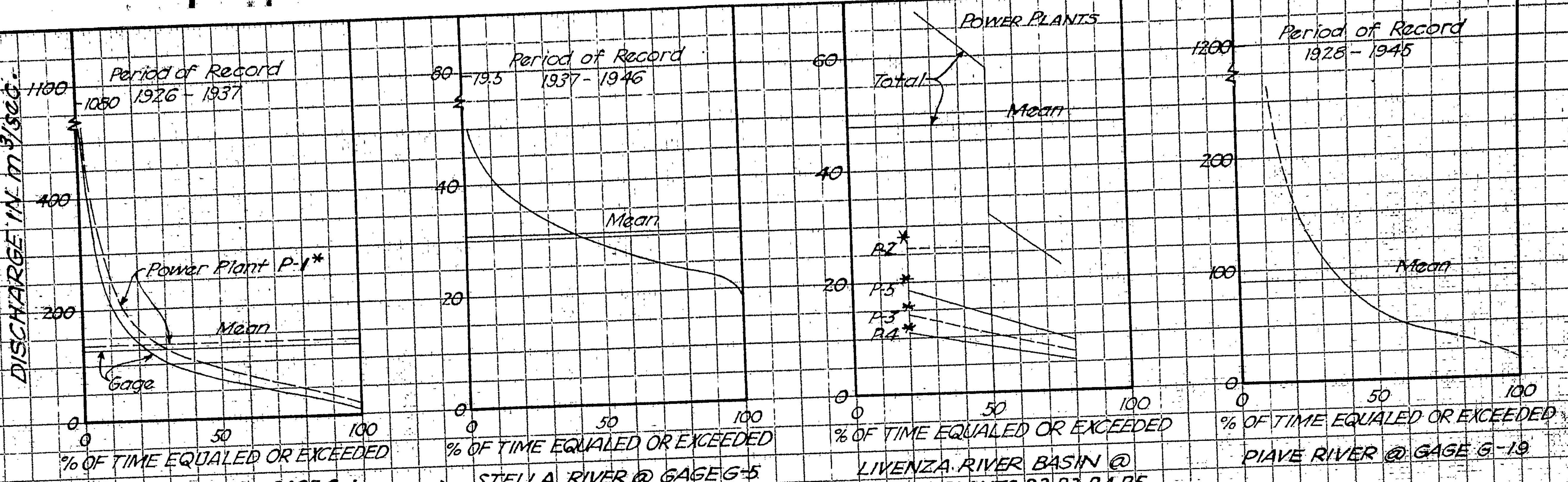

GAGE HEIGHT IN CENTIMETERS
Period of Record
1935 - 1944
850
Mean
% OF TIME EQUALED OR EXCEEDED
ISONZO RIVER
@
PONTE DI SALCANO
Gage G-2 Zero El. 55.87 meters
Period of Record
1934 - 1943
288
Mean
% OF TIME EQUALED OR EXCEEDED
CORNO RIVER
@
PORTO NOGARO
Gage G-4 Zero El. -0.99 meters
Period of Record
1934 - 1943
359
Mean
% OF TIME EQUALED OR EXCEEDED
TAGLIAMENTO RIVER
@
PONTE DI PINZANO
Gage G-10 Zero El. 160. meters
Period of Record
1932 - 1941
928
Mean
% OF TIME EQUALED OR EXCEEDED
TAGLIAMENTO RIVER
@
LATISANA
Gage G-13 Zero El. 0.0 meters
Period of Record
1937 - 1946
547
Mean
% OF TIME EQUALED OR EXCEEDED
LIVENZA RIVER
@
S. CASSIANO
Gage G-16 Zero El. 6.07 meters
Period of Record
1934 - 1943
640
Mean
% OF TIME EQUALED OR EXCEEDED
LIVENZA RIVER
@
MOTTA DI LIVENZA
Gage G-17 Zero El. 2.14 meters
Period of Record
1937 - 1946
316
Mean
% OF TIME EQUALED OR EXCEEDED
BRENTA RIVER
@
LIMENA
Gage G-23 Zero El. 14.24 meters
NOTE:
G-4 Gage Serial No. See Plate 1 & Table 3.
Gage zero elevation in meters above mean sea level.
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY
STAGE DURATION
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HB Date June 1953
Drawn by JJH

PLATE 5

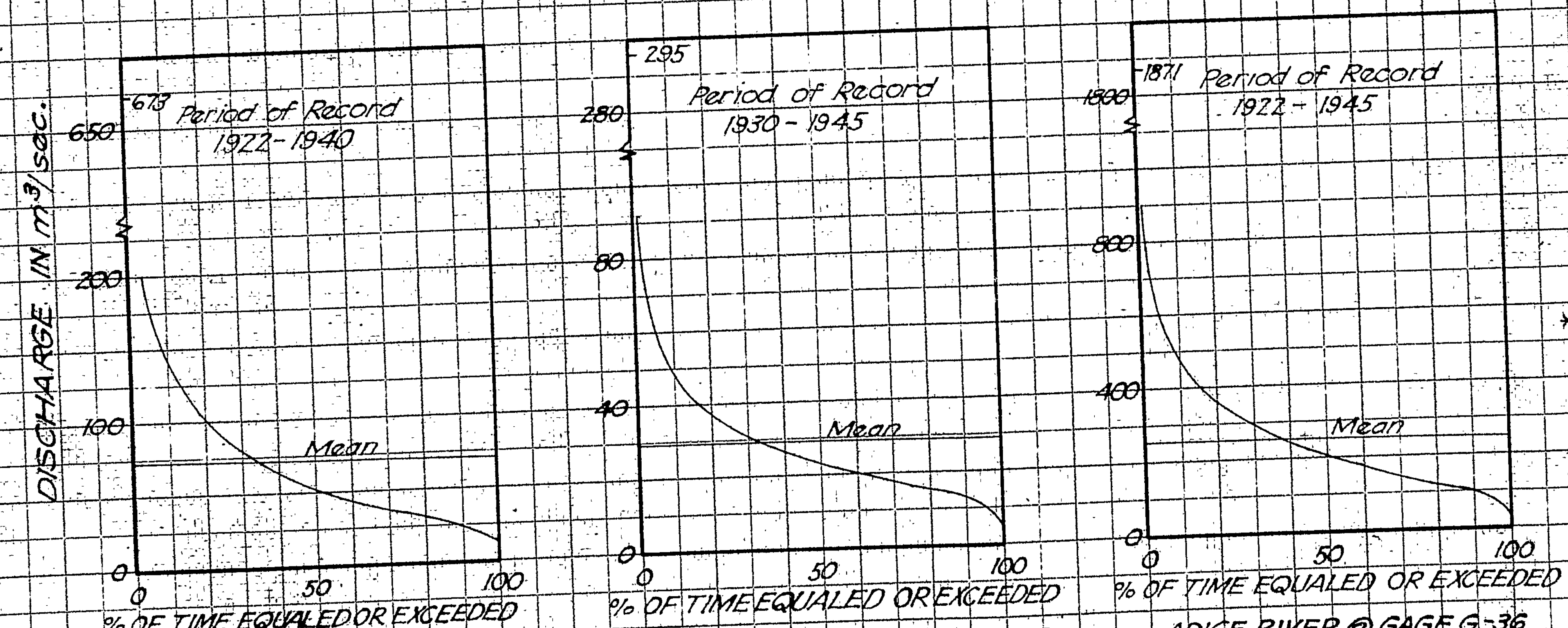


ISONZO RIVER @ GAGE G-1 & POWER PLANT P-1

STELLA RIVER @ GAGE G-5

LIVENZA RIVER BASIN @ POWER PLANTS P-2, P-3, P-4, P-5

PIAVE RIVER @ GAGE G-19



BRENTA RIVER @ GAGE G-22

BACCHIGLIONE RIVER @ GAGE G-26

ADIGE RIVER @ GAGE G-36

NOTES

G-1 Canale di Isonzo gage
G-5 Casale Sacile gage
G-19 Segusino gage
G-22 Sarson gage
G-26 Montagadella gage
G-36 Boara Pisani gage
P-1 Sagrada power plant
P-2 Caneva " "
P-3 Pardenone " "
P-4 Pte Meduna power plant
P-5 Molino power plant

*SOURCE: Servizio Idrografico, Publ. Nº 12, Fasc. VII, 1933.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

DISCHARGE DURATION

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HRB Date June 1953
Drawn by JJH

PLATE 6

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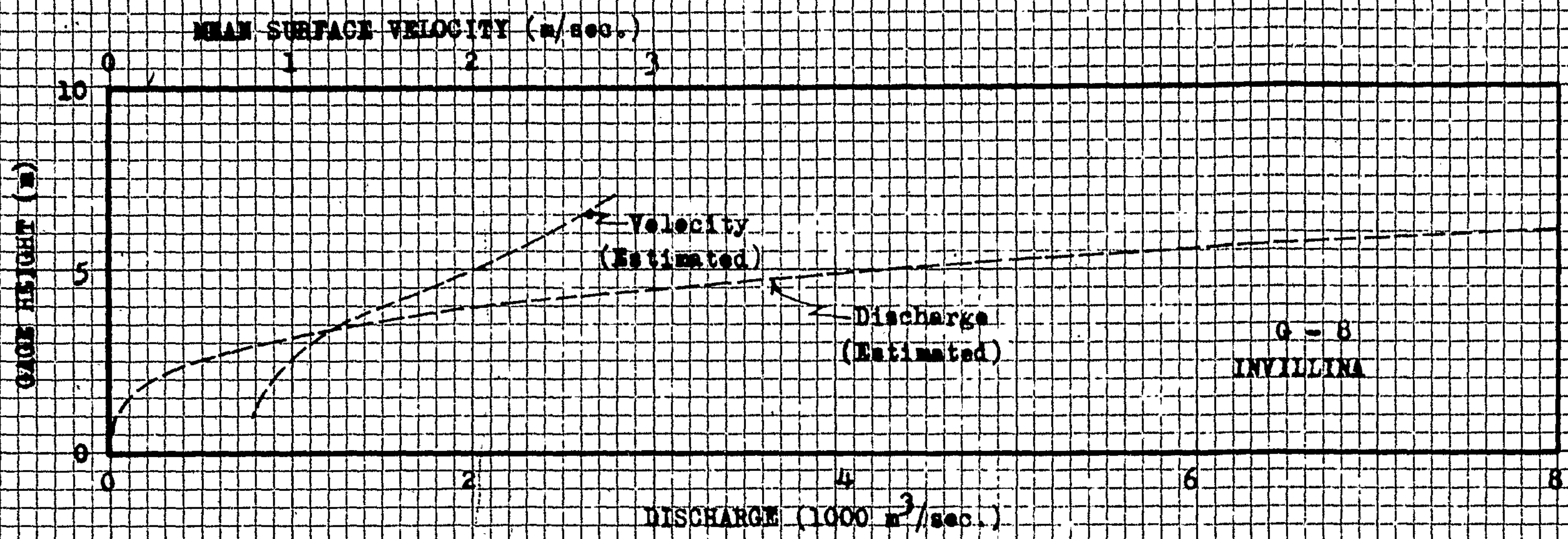
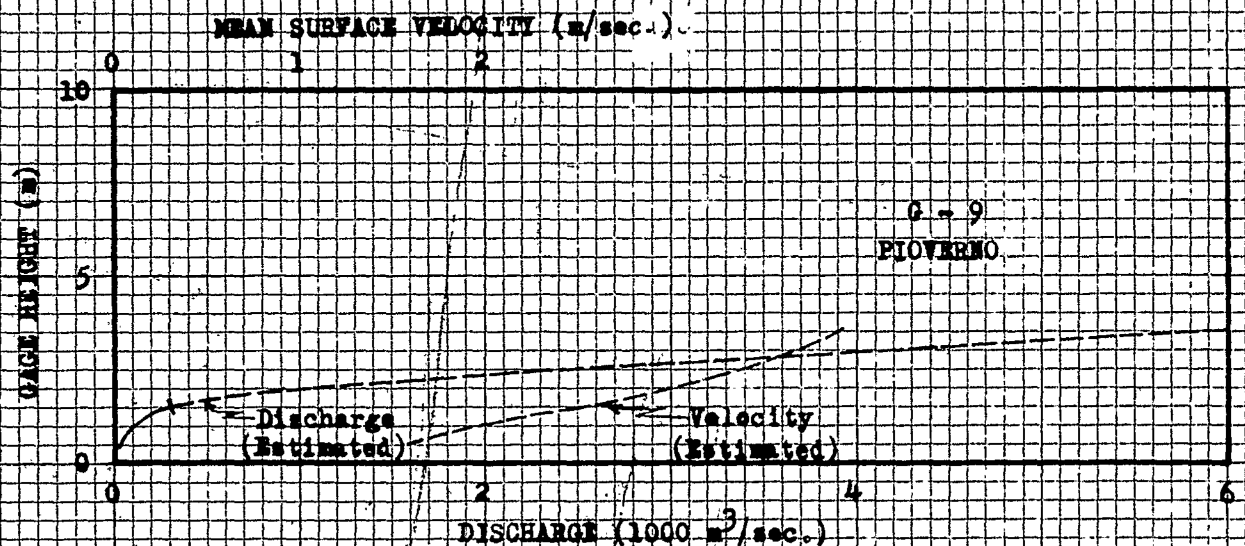
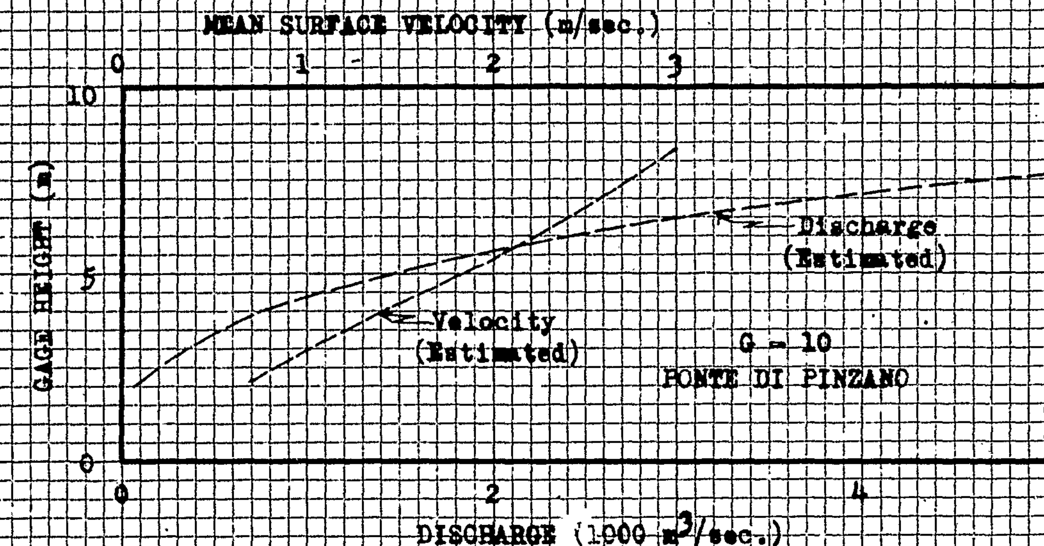
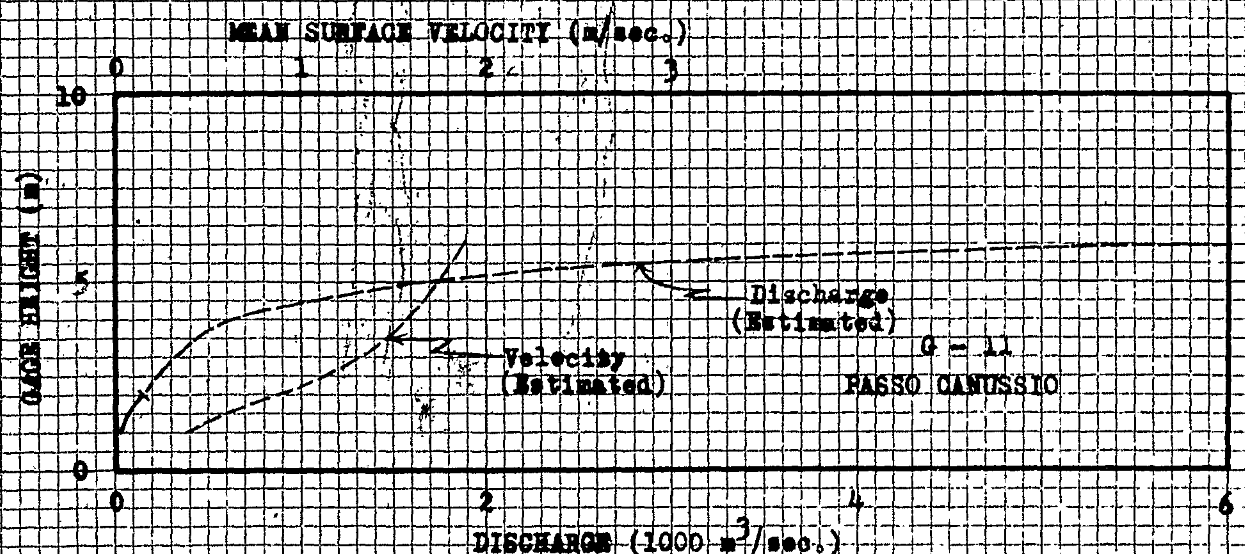
SECURITY INFORMATION









LEGEND

——— Limit of Observed Data
– – – – Estimated Extension

NOTE: Curves shown are estimated.
See Paragraphs 3-05 & 3-06.

RESTRICTED
SECURITY INFORMATION

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

DISCHARGE & VELOCITY RATING CURVES

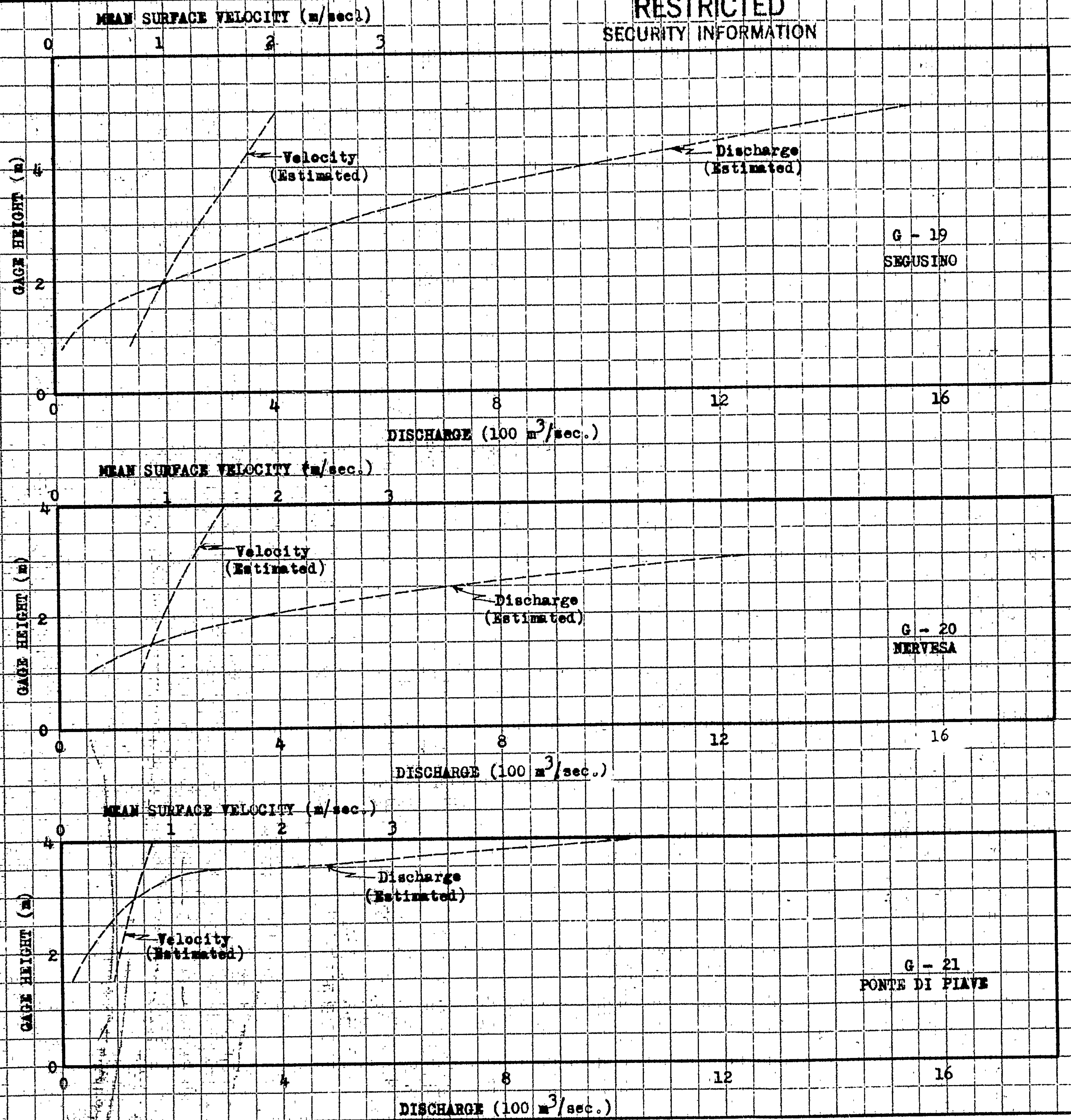
TAGLIAMENTO RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by FBB
Drawn by JJH
Date July 1953

PLATE 7a

RESTRICTED
SECURITY INFORMATION



LEGEND

——— Limit of Observed Data

– – – – Estimated Extension

NOTE: Curves shown are estimated.

See Paragraphs 3-05 & 3-06.

RESTRICTED
SECURITY INFORMATION

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

DISCHARGE & VELOCITY RATING CURVES

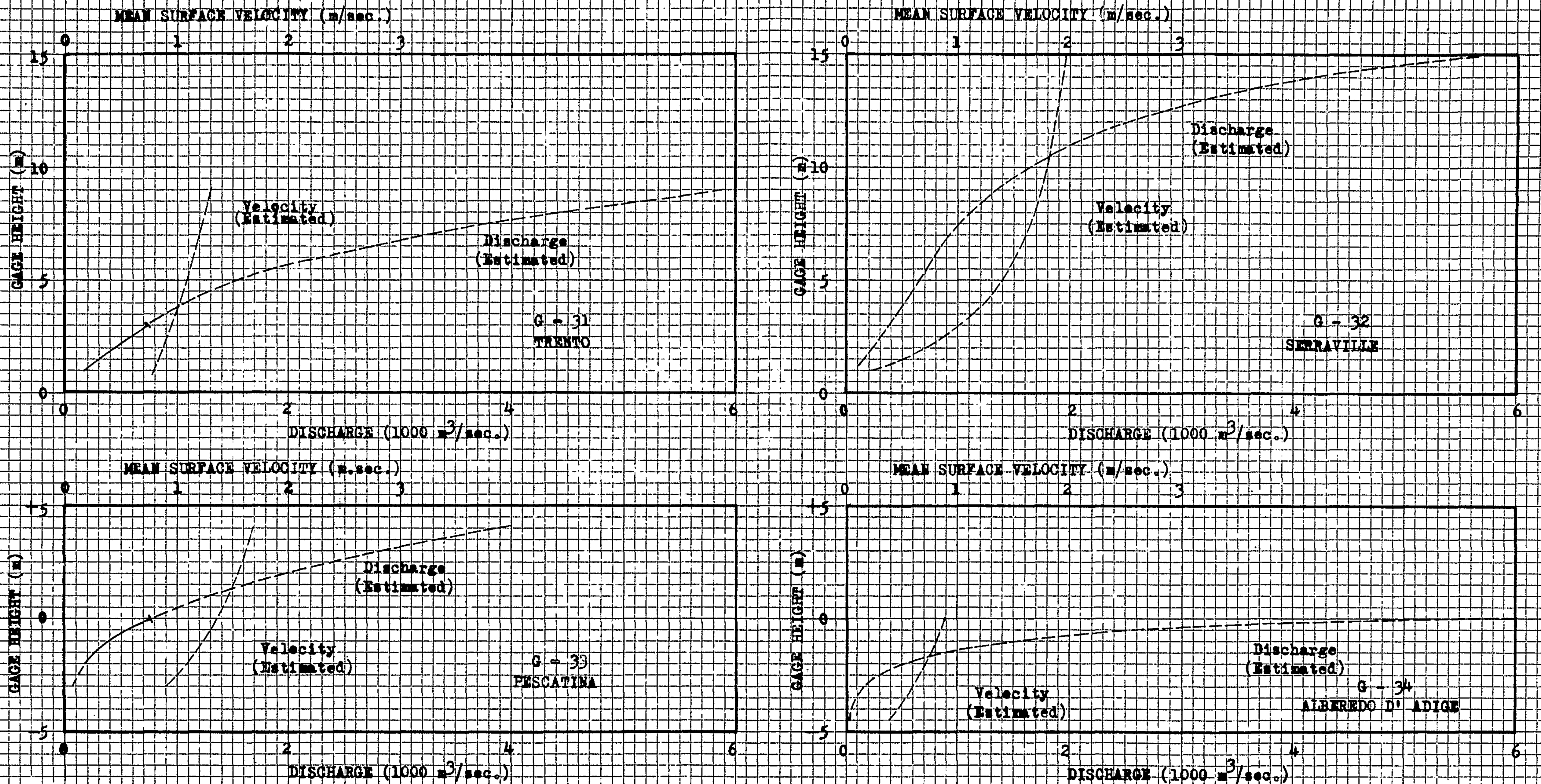
PIAVE RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS

Prepared by EBB Date July 1953
Drawn by JJH

PLATE 7b

RESTRICTED
SECURITY INFORMATION



LEGEND
Limit of Observed Data
Estimated Extension
NOTE: Curves shown are estimated.
See Paragraphs 3-05 & 3-06.

RESTRICTED
SECURITY INFORMATION

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

DISCHARGE & VELOCITY RATING CURVES ADIGE RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by FBB Date JULY 1953
Drawn by JJH

PLATE 7c

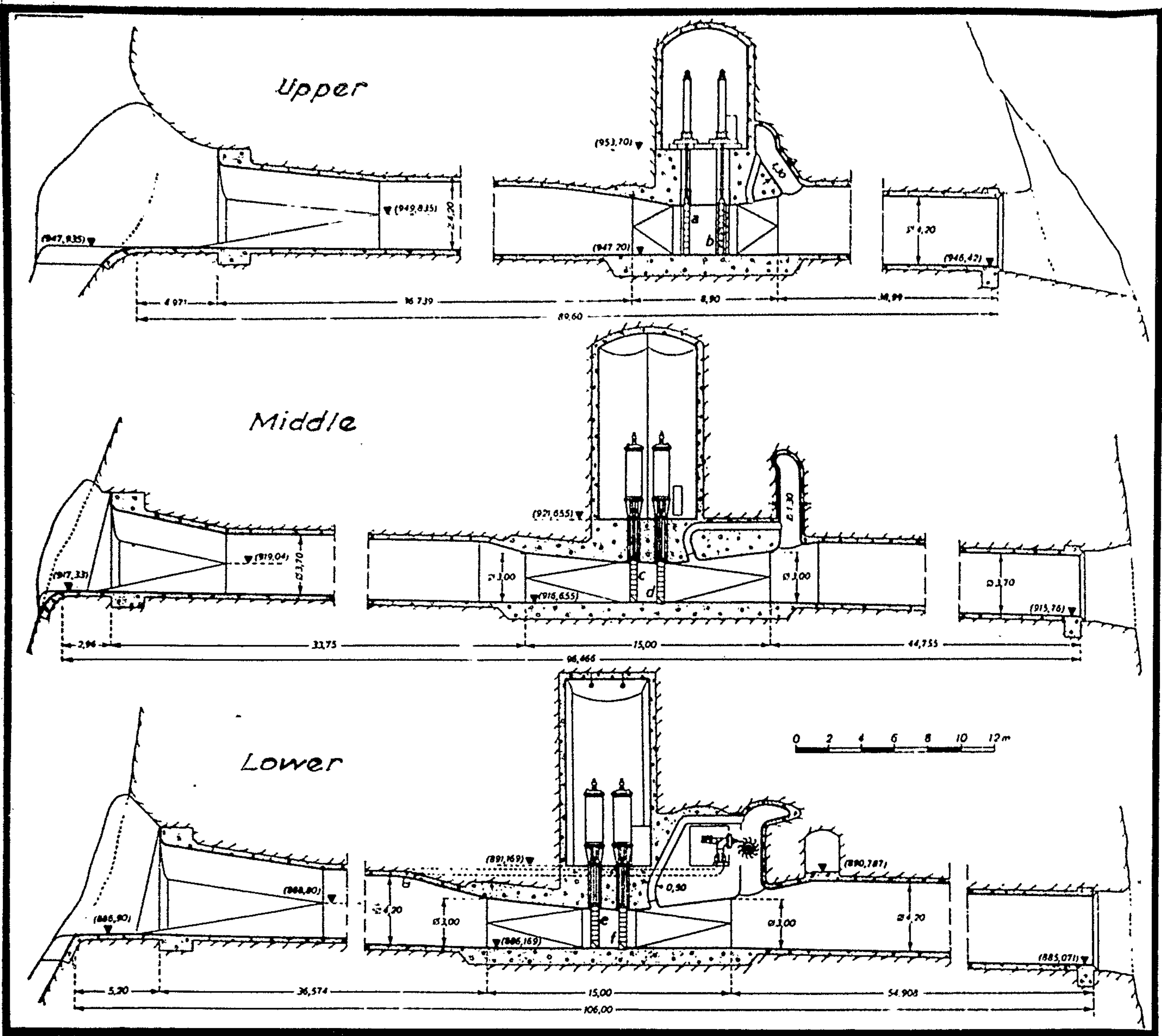


Fig.I - SCOUR TUNNELS & GATES

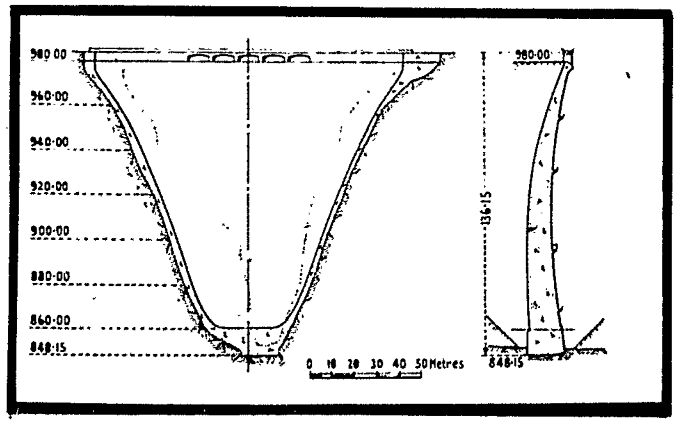


Fig. II - ELEVATION & CROSS SECTION

1

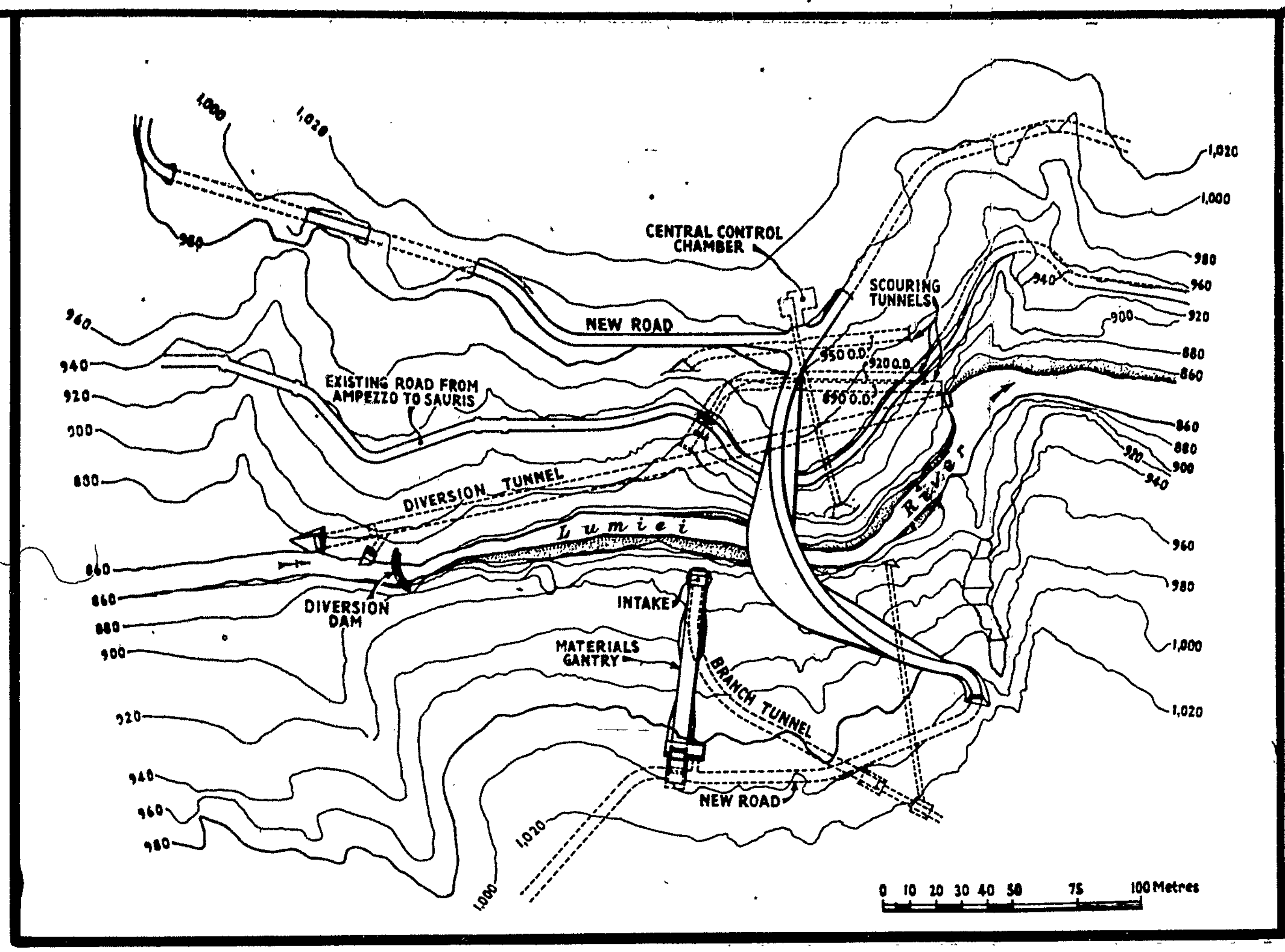


Fig. III - PLAN

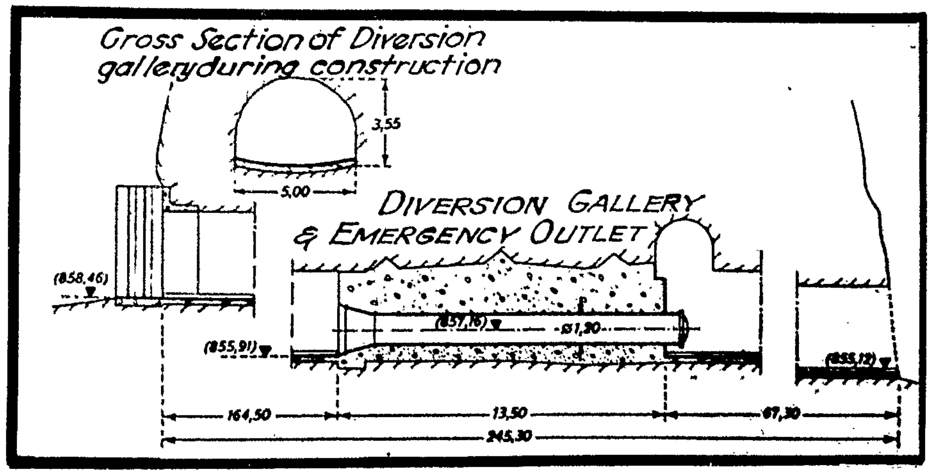
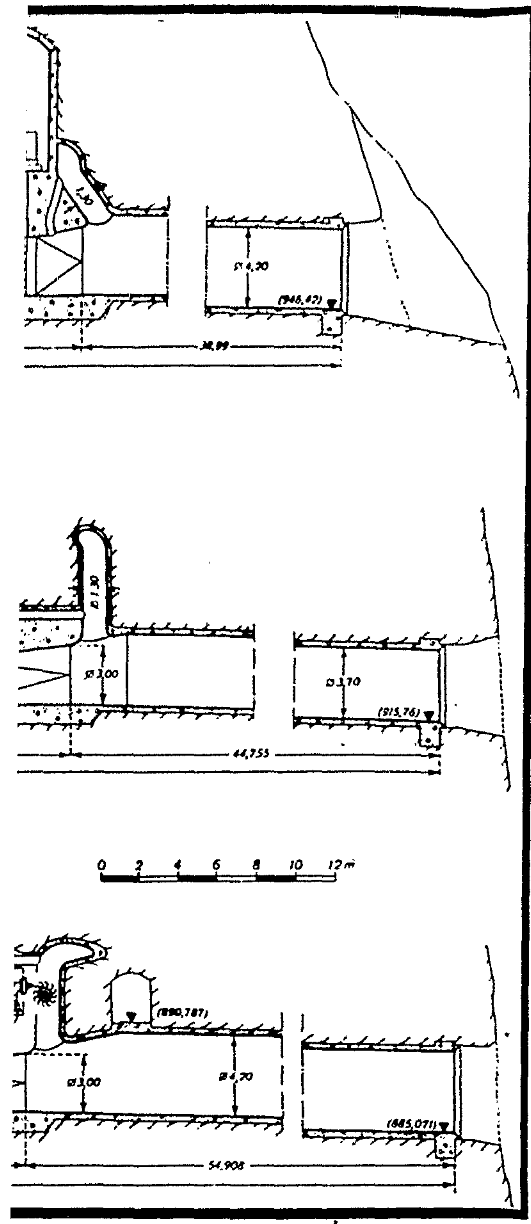
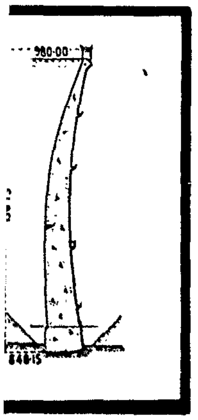


Fig. IV - EMERGENCY OUTLET

SOURCE:

Fig. I "L'Energia Ele
page 419.
Fig. II "Water Power",
page 146.
Fig. III "Water Power",
page 146.
Fig. IV "L'Energia Ele
1948, page 42
Fig. V "The Engineer"
page 446.





CTION

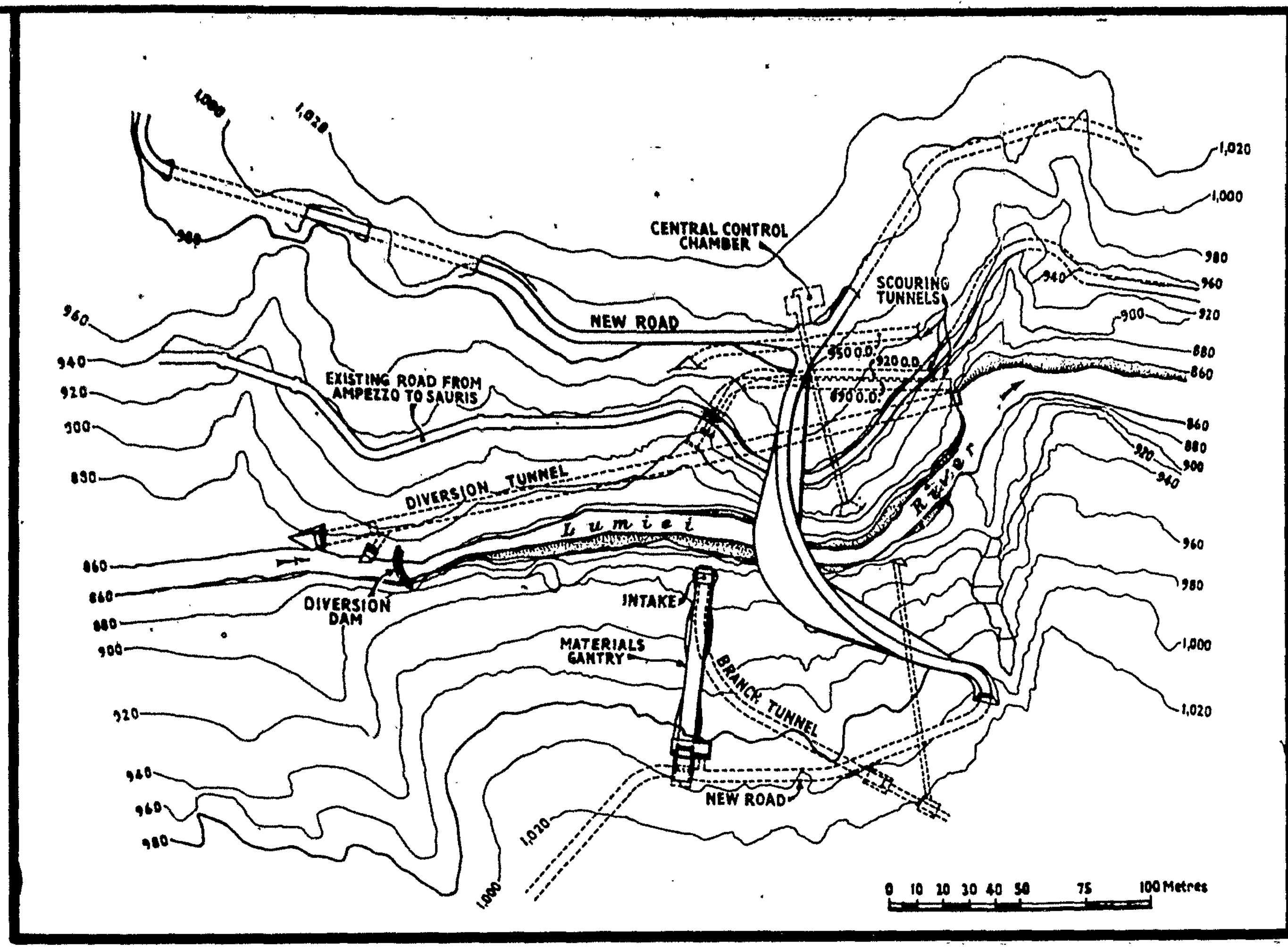


Fig. III - PLAN

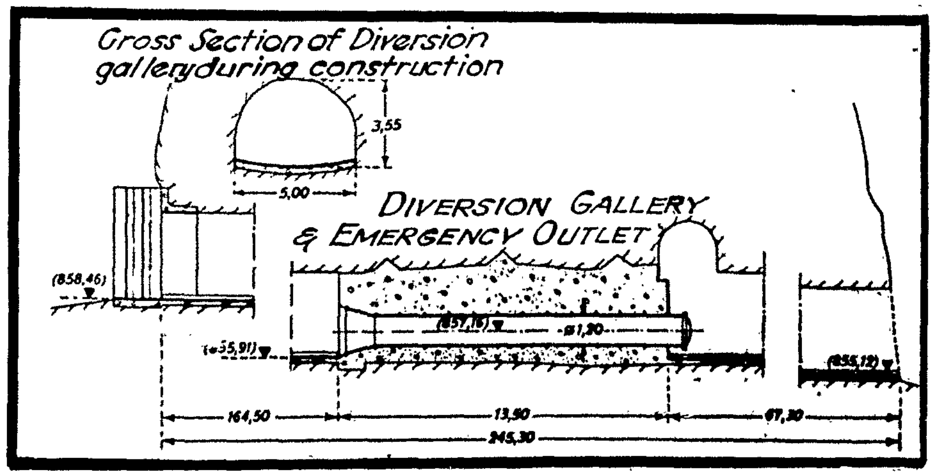


Fig. IV - EMERGENCY OUTLET

Fig. V - GENERAL VIEW OF DAM

2

SOURCE:

Fig. I "L'Energia Elettrica", August 1948, page 419.

Fig. II "Water Power", July-August, 1950, page 146.

Fig. III "Water Power", July-August, 1950, page 146.

Fig. IV "L'Energia Elettrica ", August 1948, page 420.

Fig. V "The Engineer", 27 March 1953, page 446.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

SKETCHES OF DAMS

LUMIEI

MILITARY HYDROLOGY R.& D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date June 1953
Drawn by ______

PLATE 8a

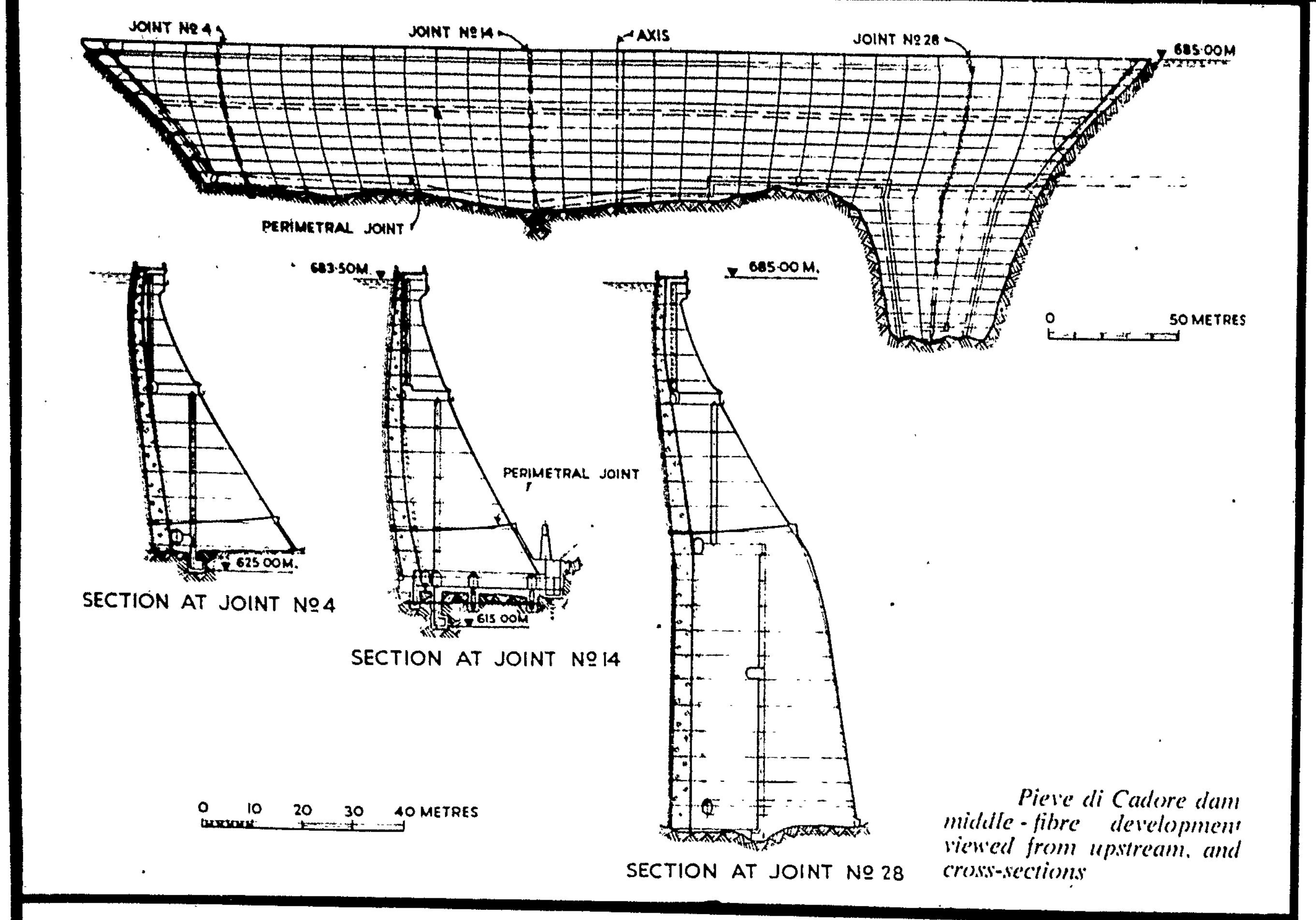


Fig. I - ELEVATION & CROSS SECTIONS

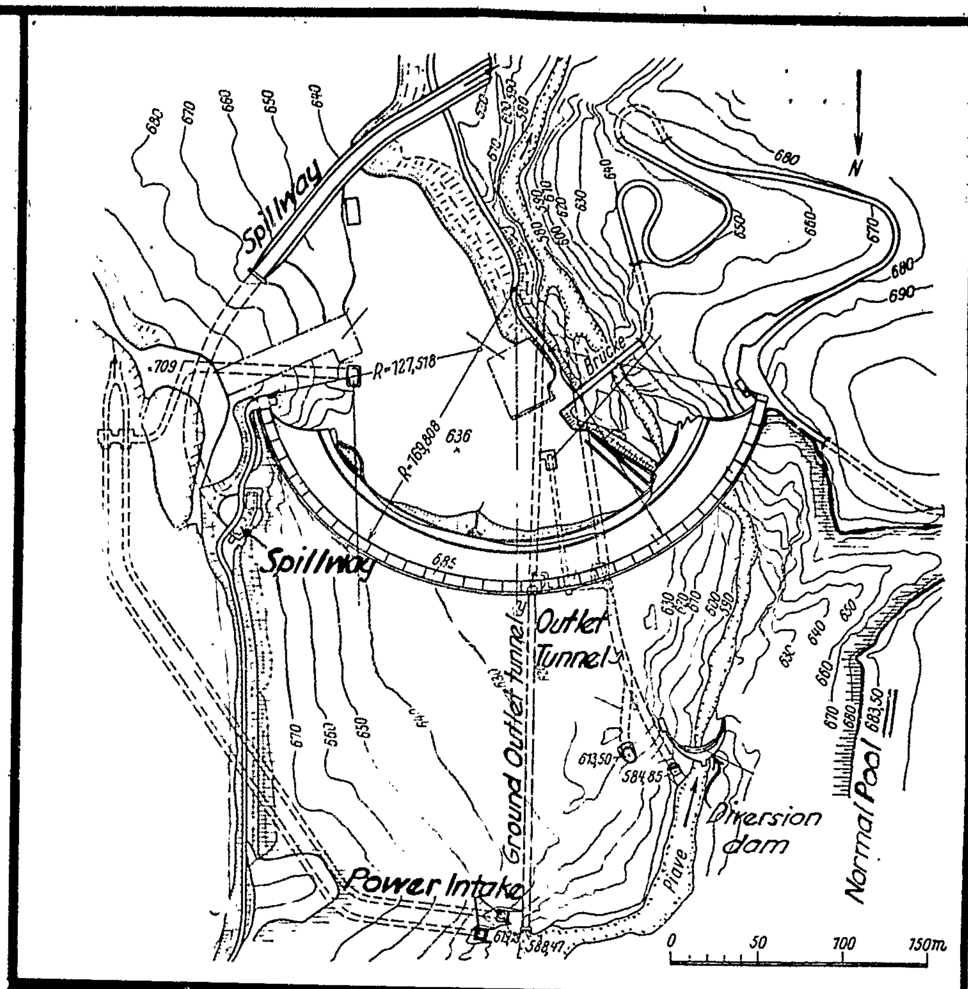


Fig. III - PLAN

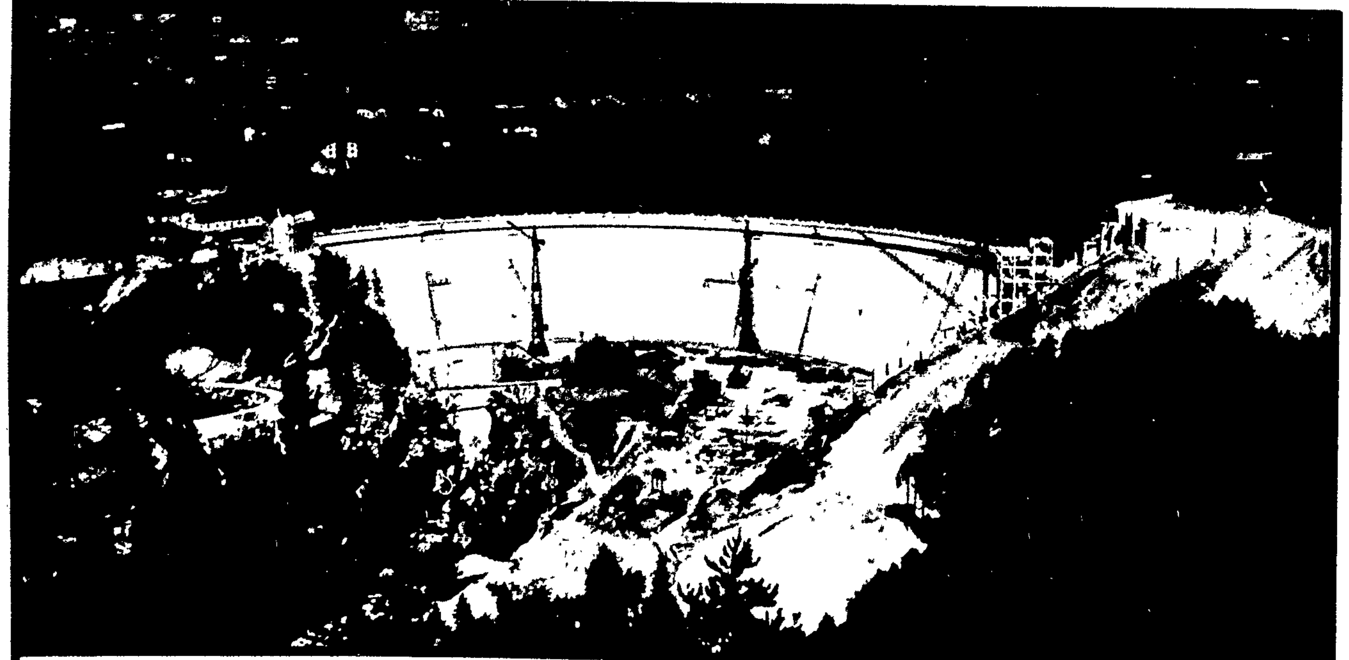


Fig. II - GENERAL VIEW OF DAM

SOURCE:

Fig. I "Water Power", May 1952, page 166.
Fig. II "L'Energia Elettrica", March 1951, page 175.
Fig. III "Die Bautechnik", November 1951, page 277.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

SKETCHES OF DAMS

PIEVE DI CADORE

MILITARY HYDROLOGY R & D. BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date June 1953
Drawn by ______

PLATE 8b

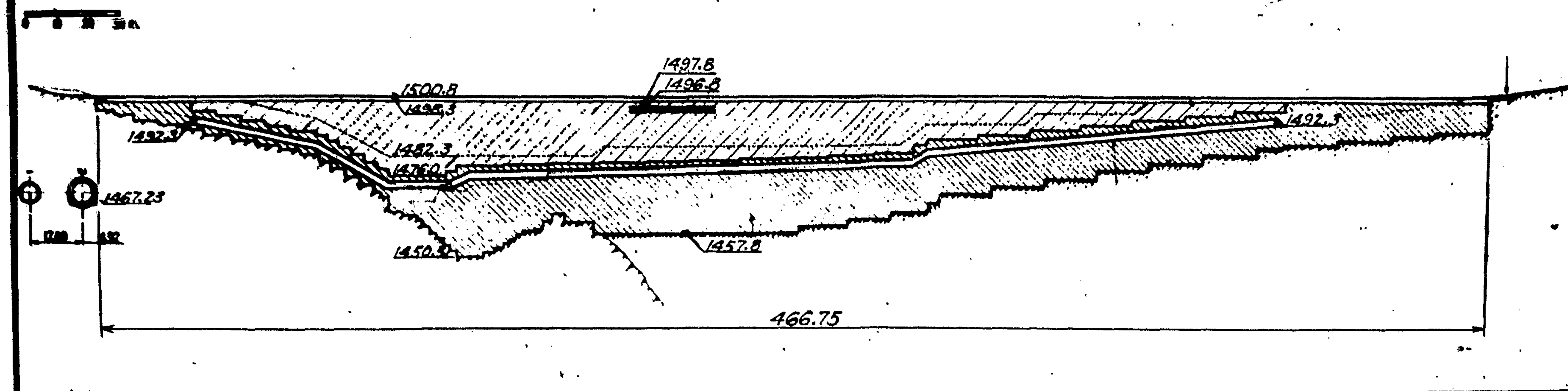


Fig. I - ELEVATION

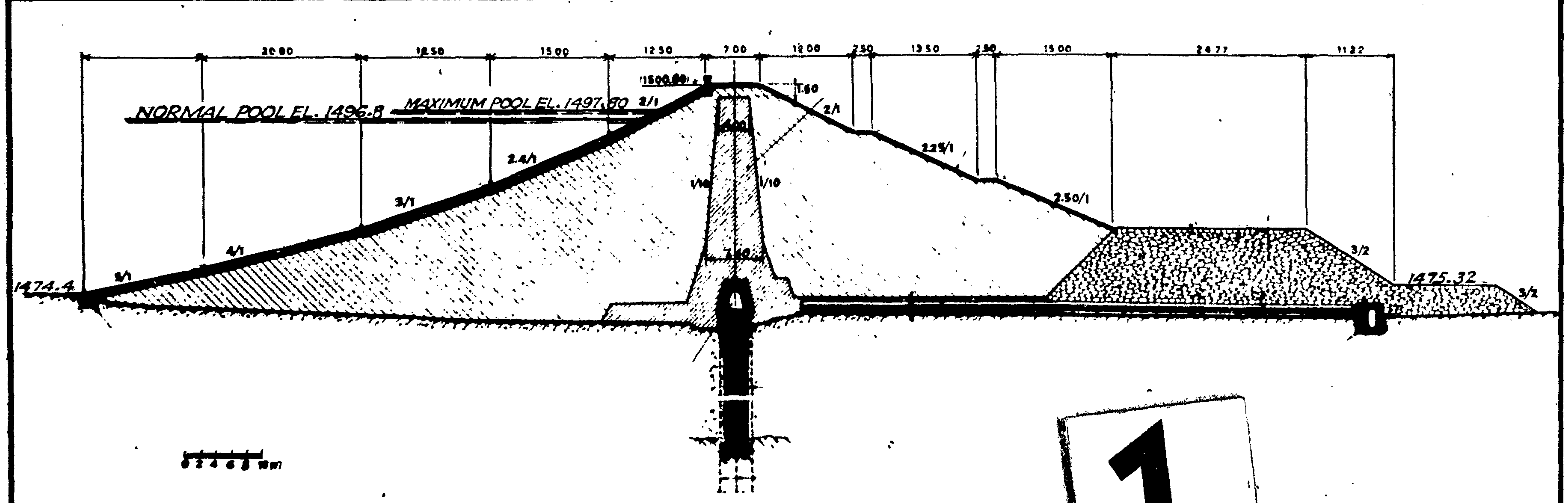


Fig. II - CROSS SECTION

SOURCE:

"L'Elettrotecnica";
pages 167 & 168.

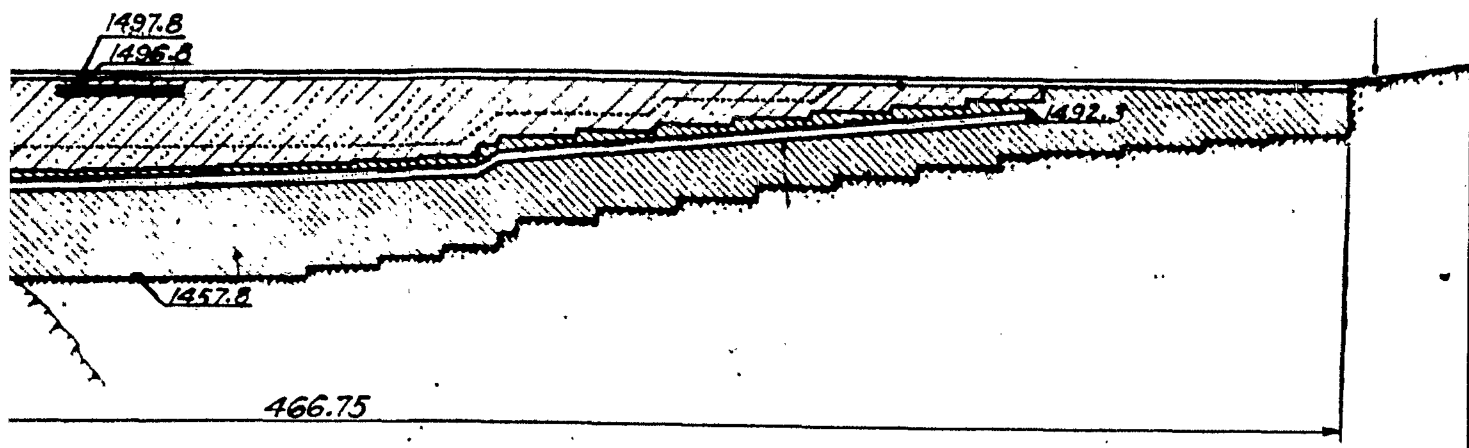


Fig. I - ELEVATION

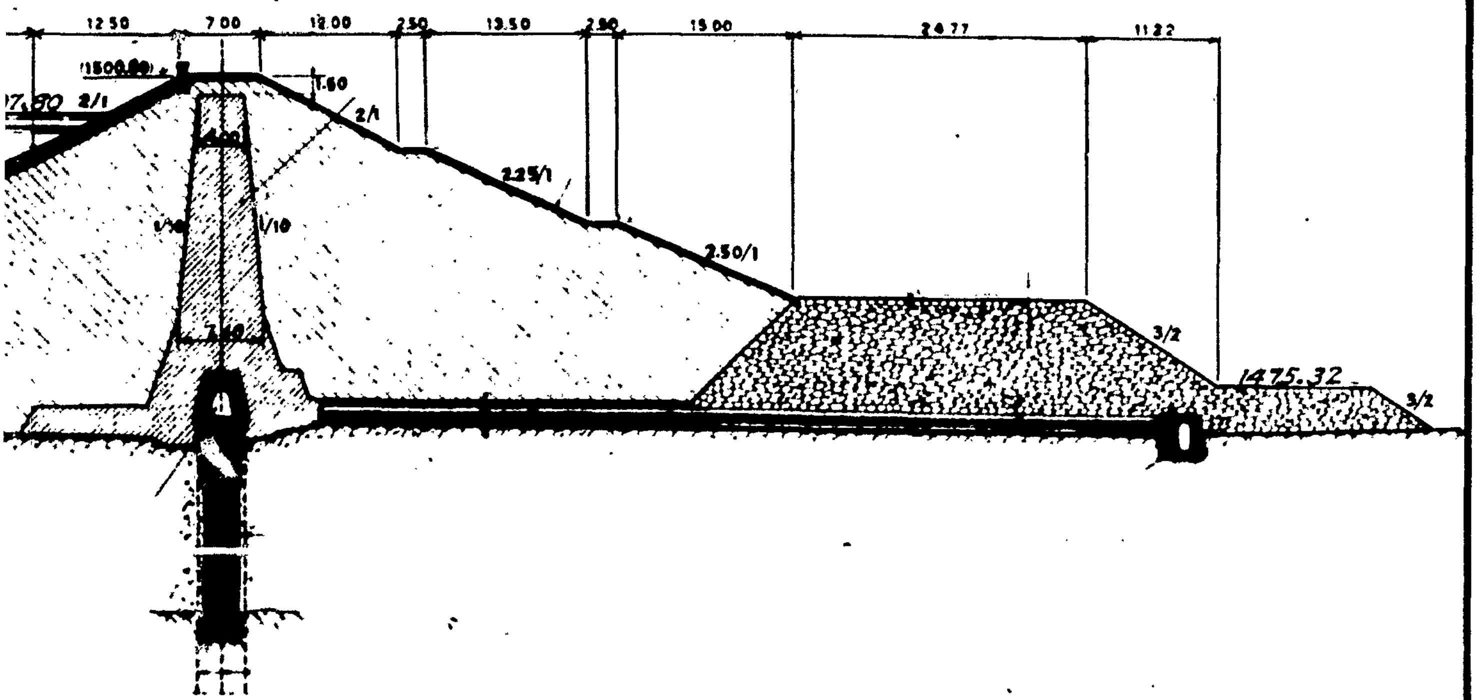


Fig. II - CROSS SECTION

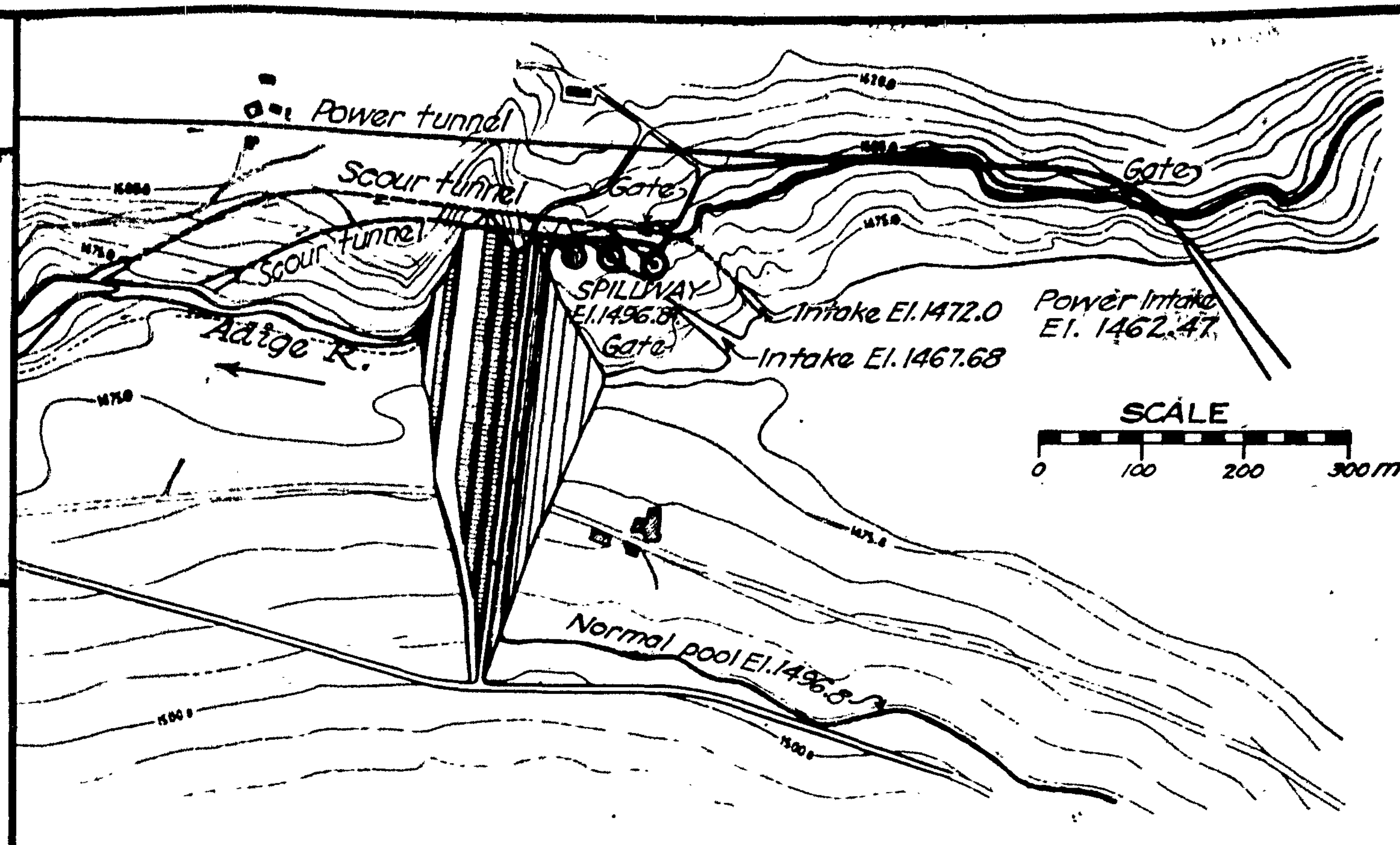


Fig. III - PLAN

2

SOURCE:

"L'Elettrotecnica"; April 1950,
pages 167 & 168.

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

SKETCHES OF DAMS

S. VALENTINO

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date June 1953
Drawn by ______

PLATE 8c

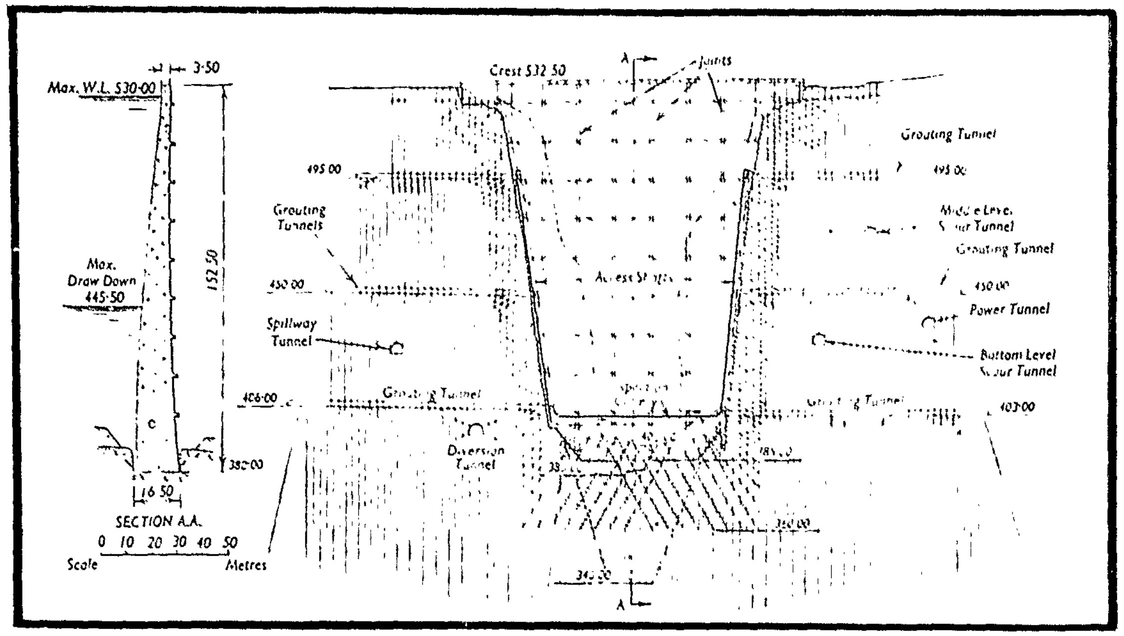


Fig. I - CROSS SECTION & GROUT SCREEN

Fig. II - VIEW FROM DOWNSTREAM

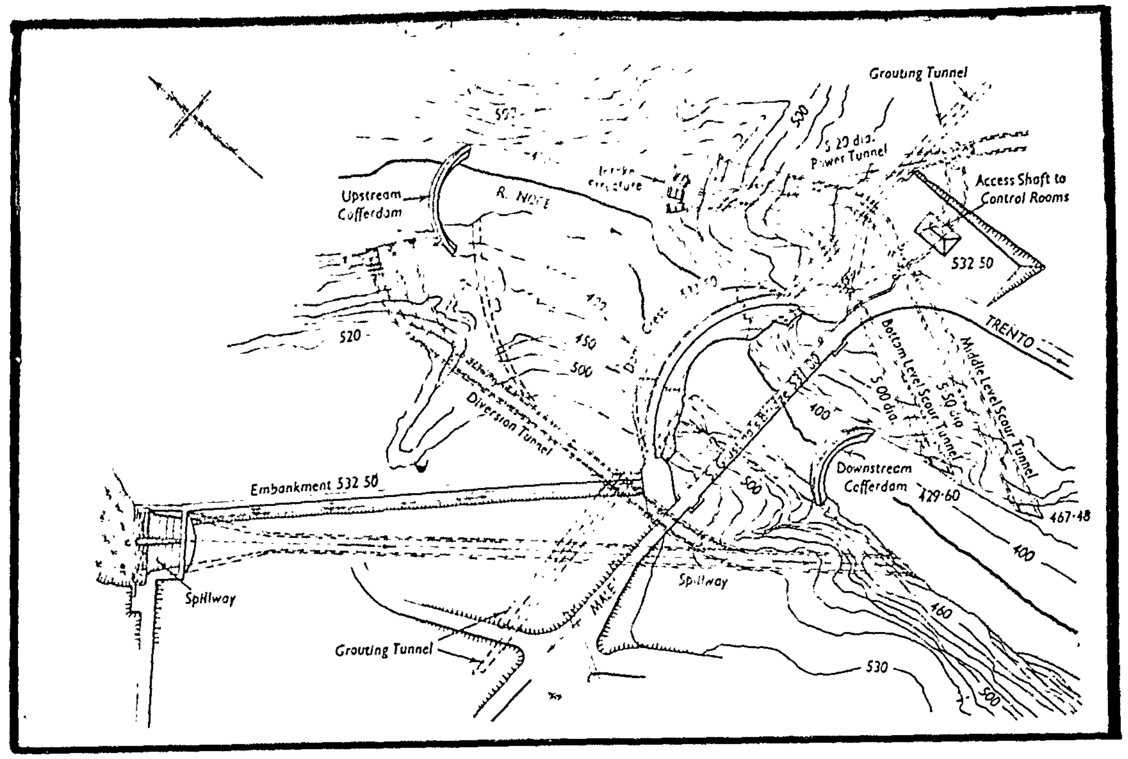


Fig. III - PLAN

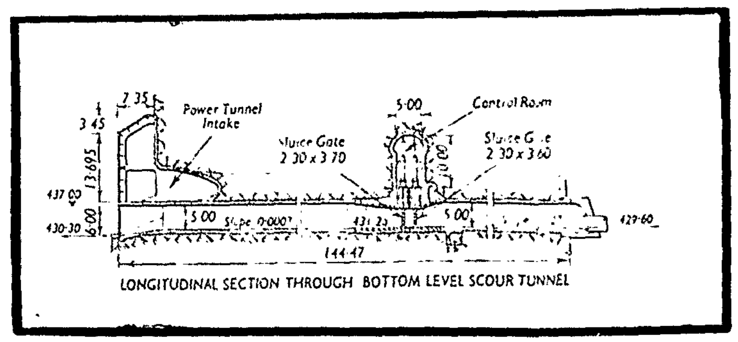


Fig. IV - LONGITUDINAL SECTION THROUGH BOTTOM LEVEL SCOUR TUNNEL

SOURCE:
"Tho Engineer", 27 February 1953, pages 302 & 303.

VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

SKETCHES OF DAMS

S. GIUSTINA

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by JJH Date June 1953
Drawn by ______

PLATE 8 d

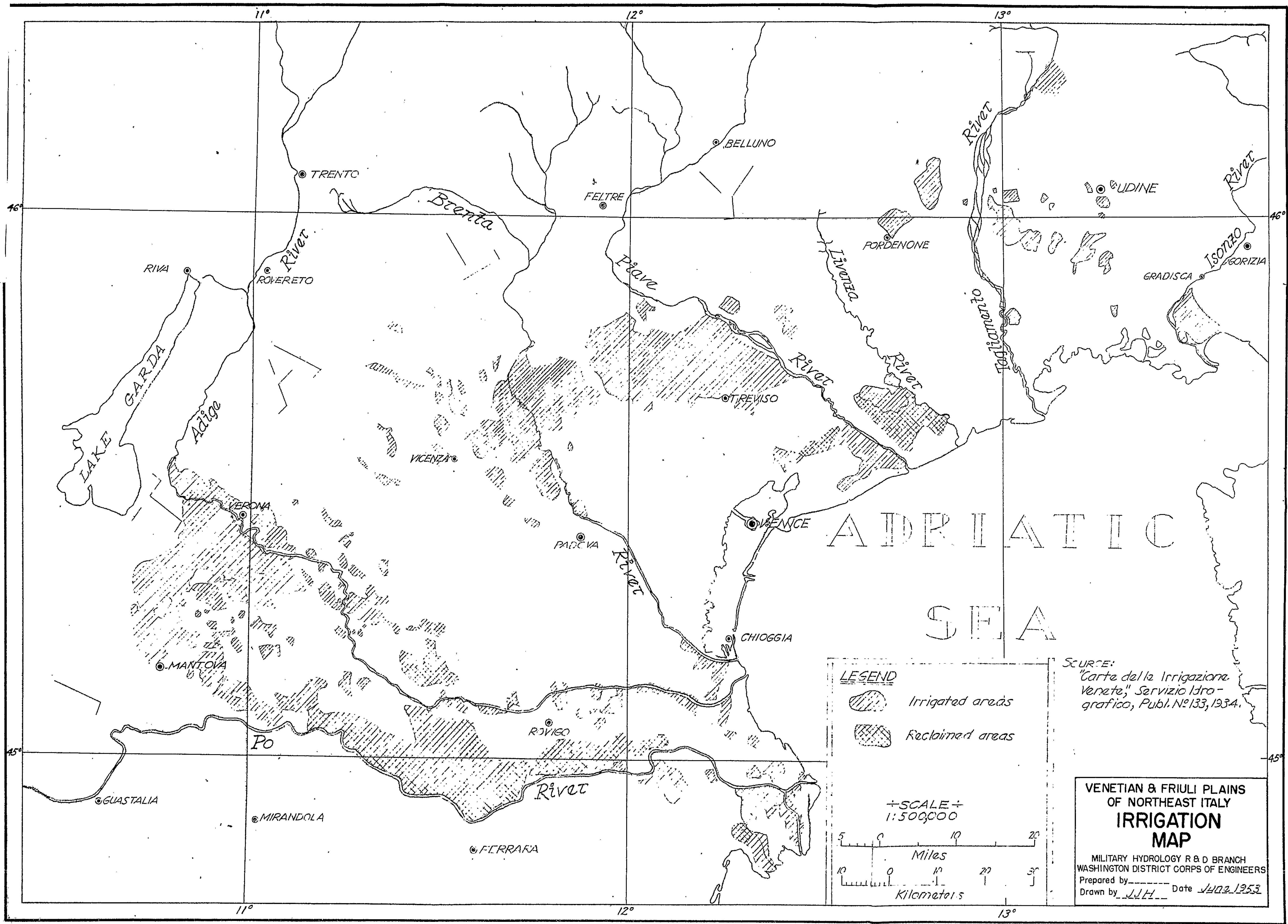
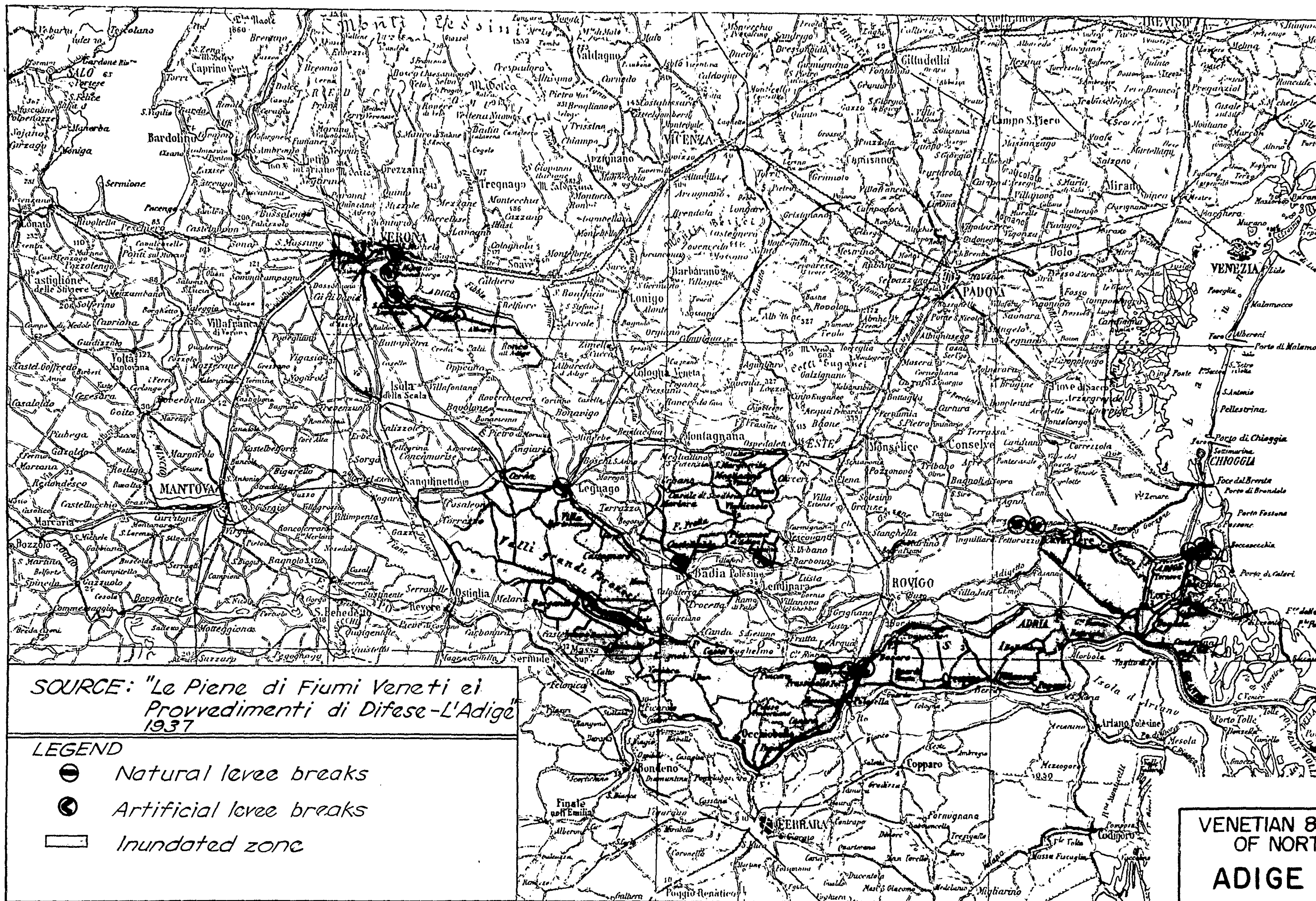

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY
IRRIGATION
MAP
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by
Drawn by JJH
Date JAN 2 1953
LEGEND
Irrigated areas
Reclaimed areas
SCALE
1:500,000
Miles
Kilometers
Source:
"Carte della Irrigazione Venete," Servizio Idrografico, Publ. No 133, 1934.
ADRIATIC
SEA
TRENTO
ROVERETO
RIVA
LAKE GARDA
Adige
River
Brenta
FELTRE
BELLUNO
Piave
River
Livenza
River
PORDENONE
Tagliamento
River
UDINE
GRADISCA
GORIZIA
Isonzo
River
TREVISO
VICENZA
VERONA
PADOVA
VENICE
CHIOGGIA
ROVIGO
MANTOVA
Po
River
GUASTALIA
MIRANDOLA
FERRARA
11°
12°
13°
45°
46°

PLATE 9



VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

ADIGE R. FLOOD OF 1882

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by J.I.H. Date June 1953
Drawn by ______

PLATE 10

CONFIDENTIAL
SECURITY INFORMATION

1

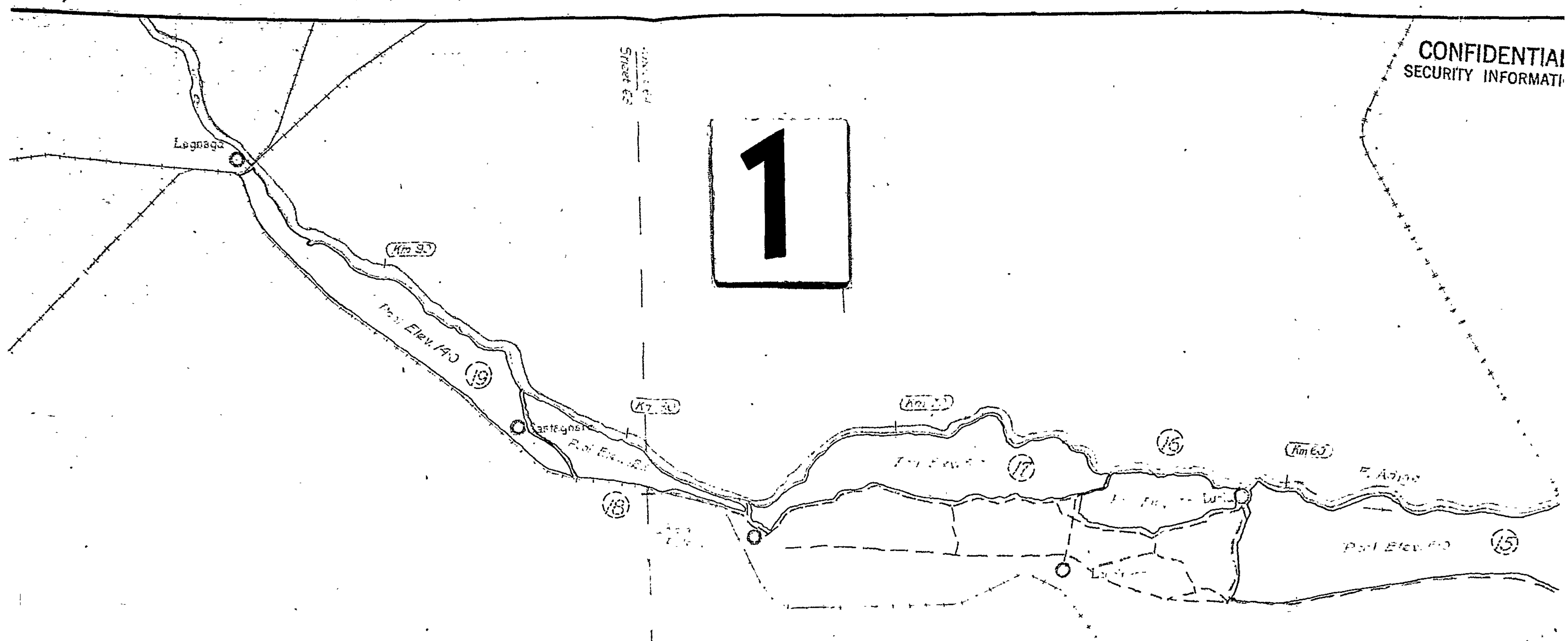


Fig. I Adige River

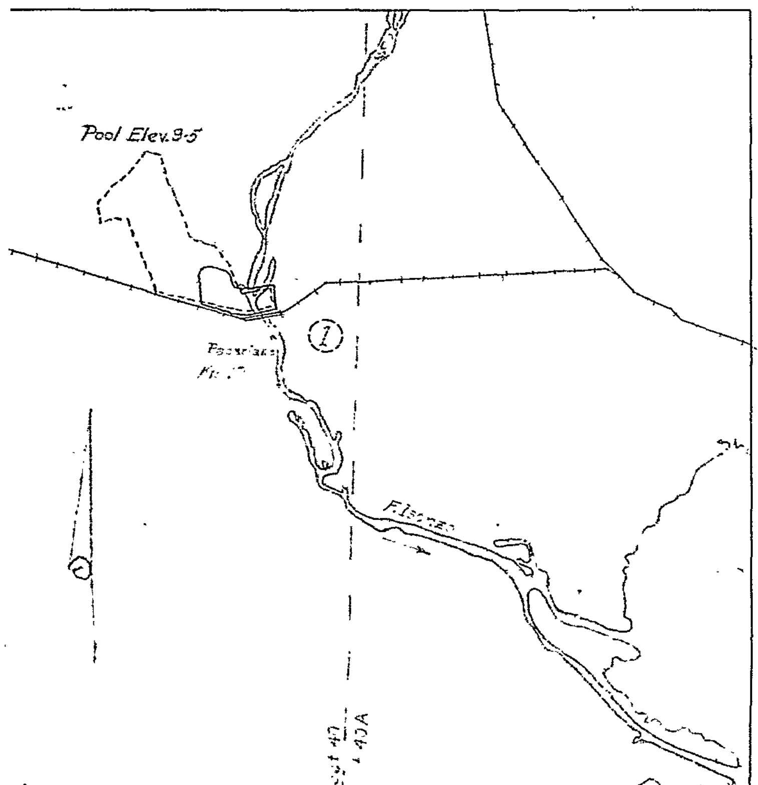


Fig. II Isonzo River

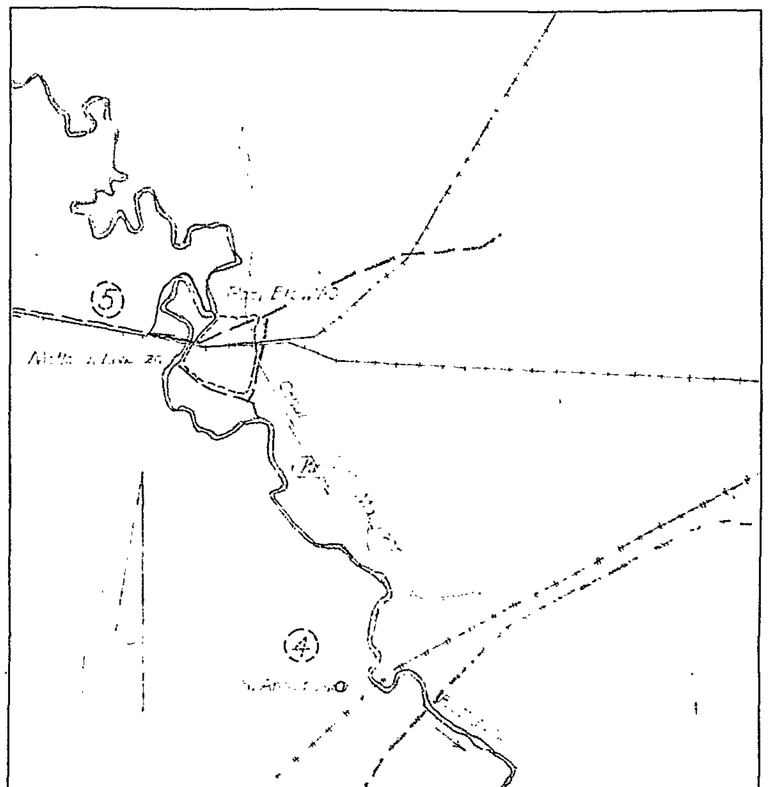


Fig. III Livenza River

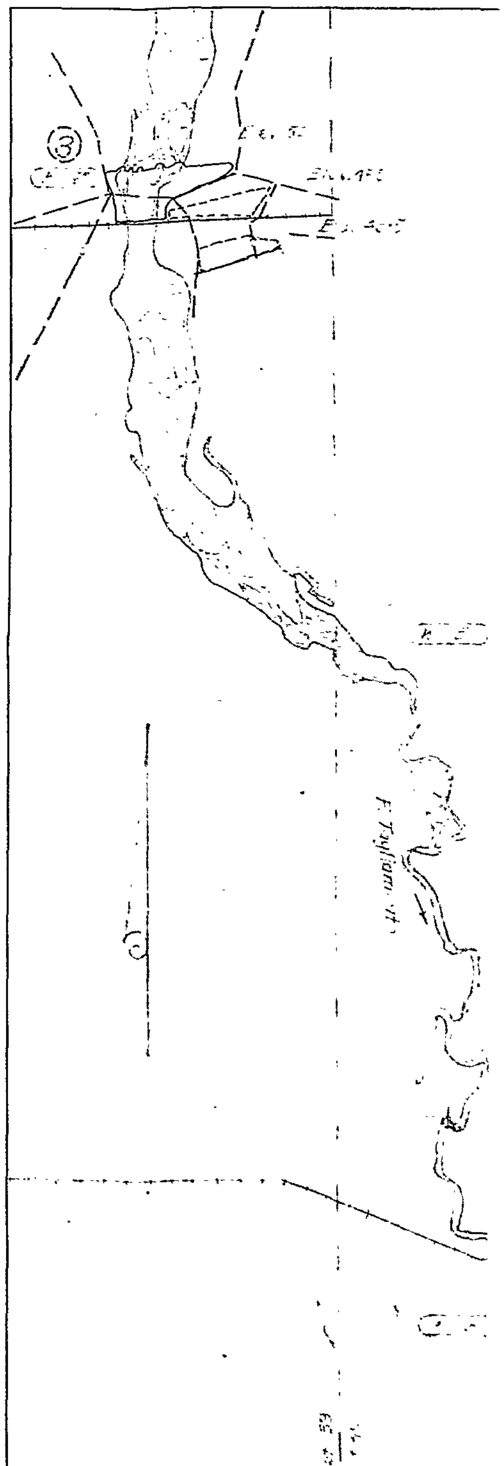
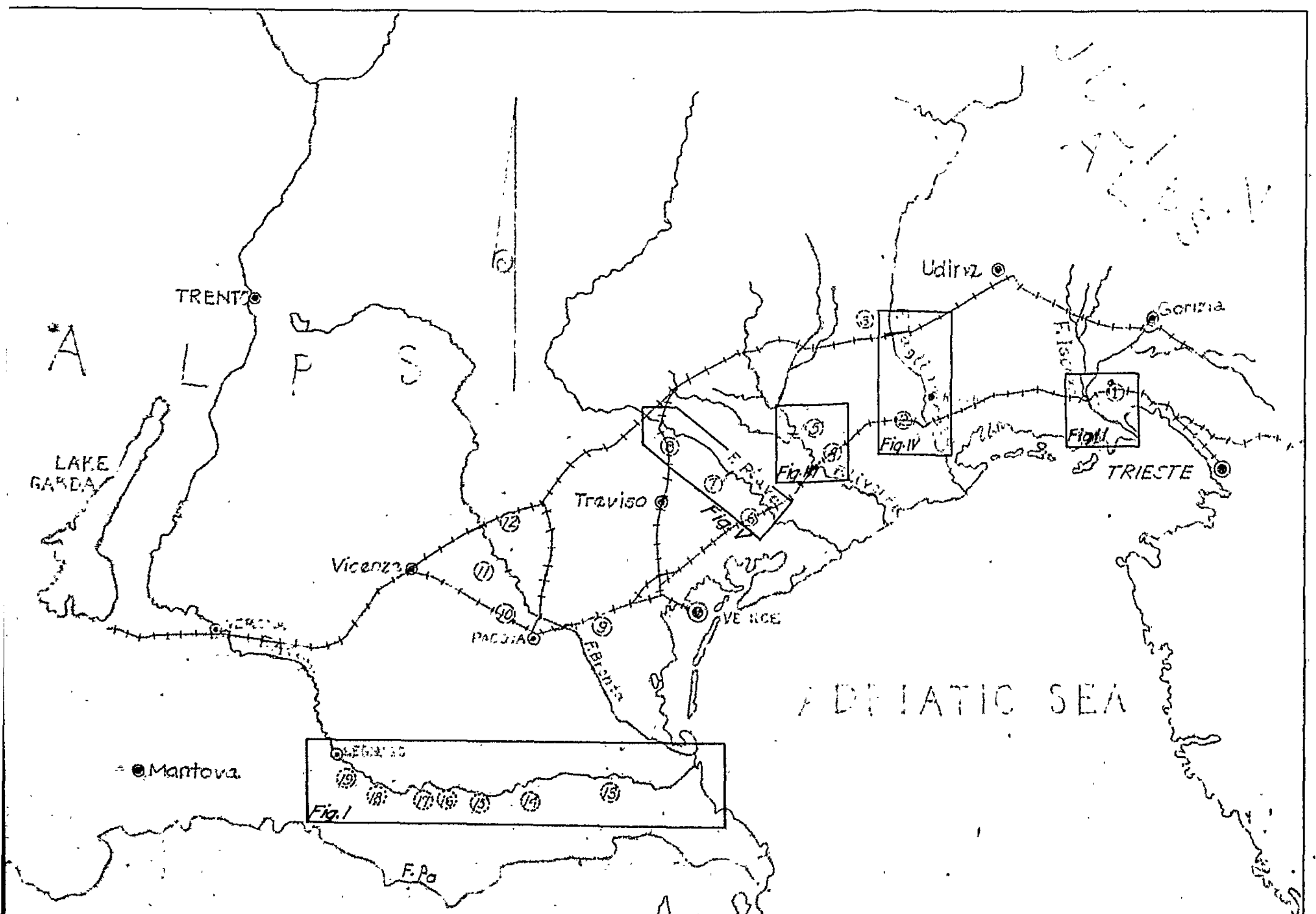


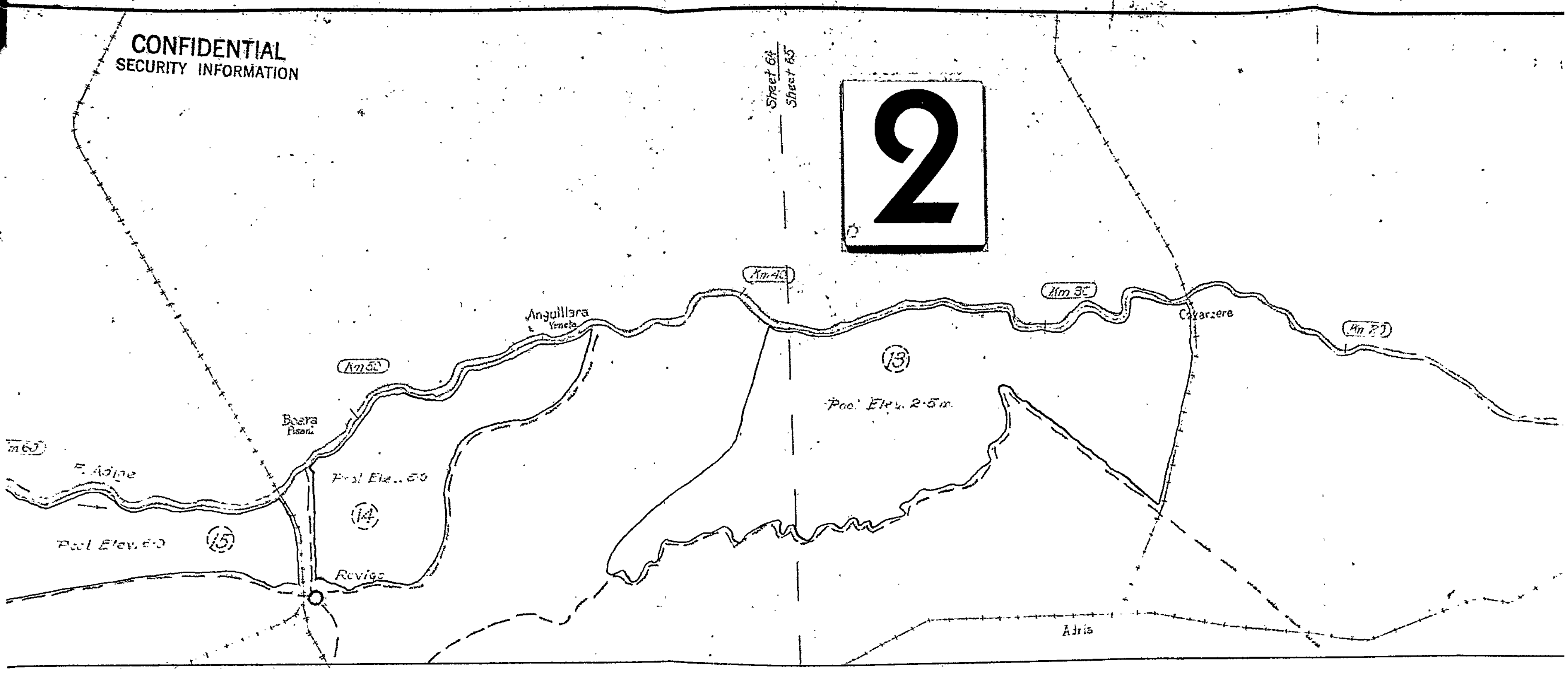
Fig. IV Tagliamento River

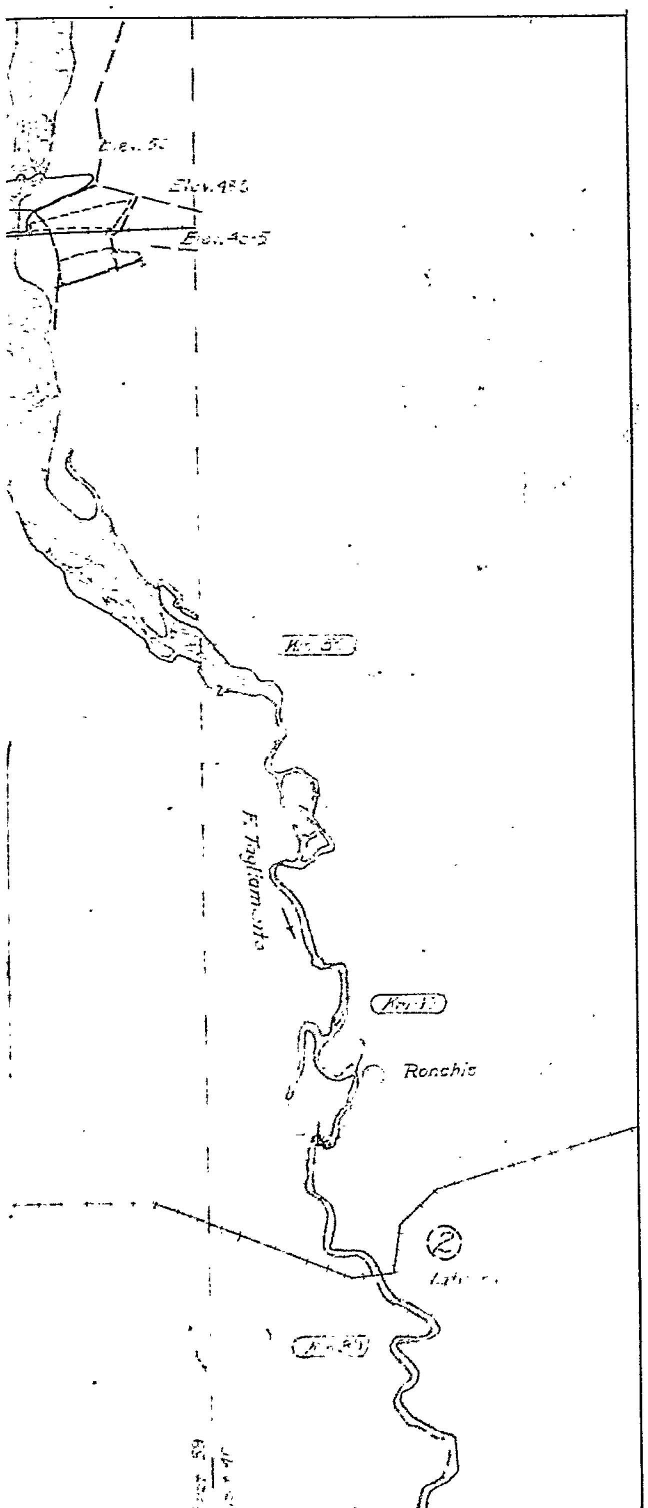


—KEY MAP—

CONFIDENTIAL
SECURITY INFORMATION

2





Tagliamento River

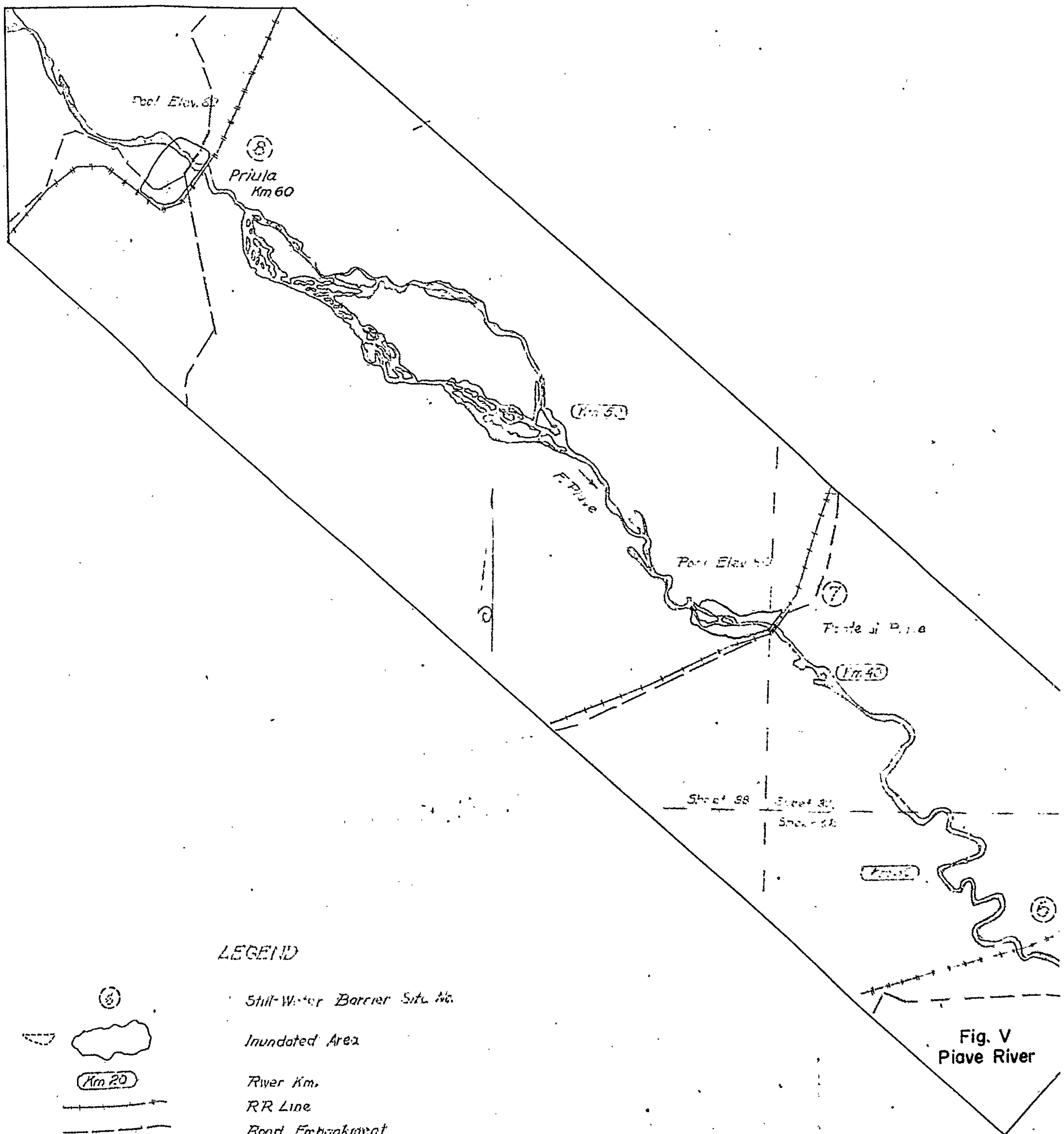
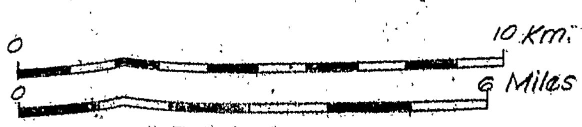


Fig. V
Piave River

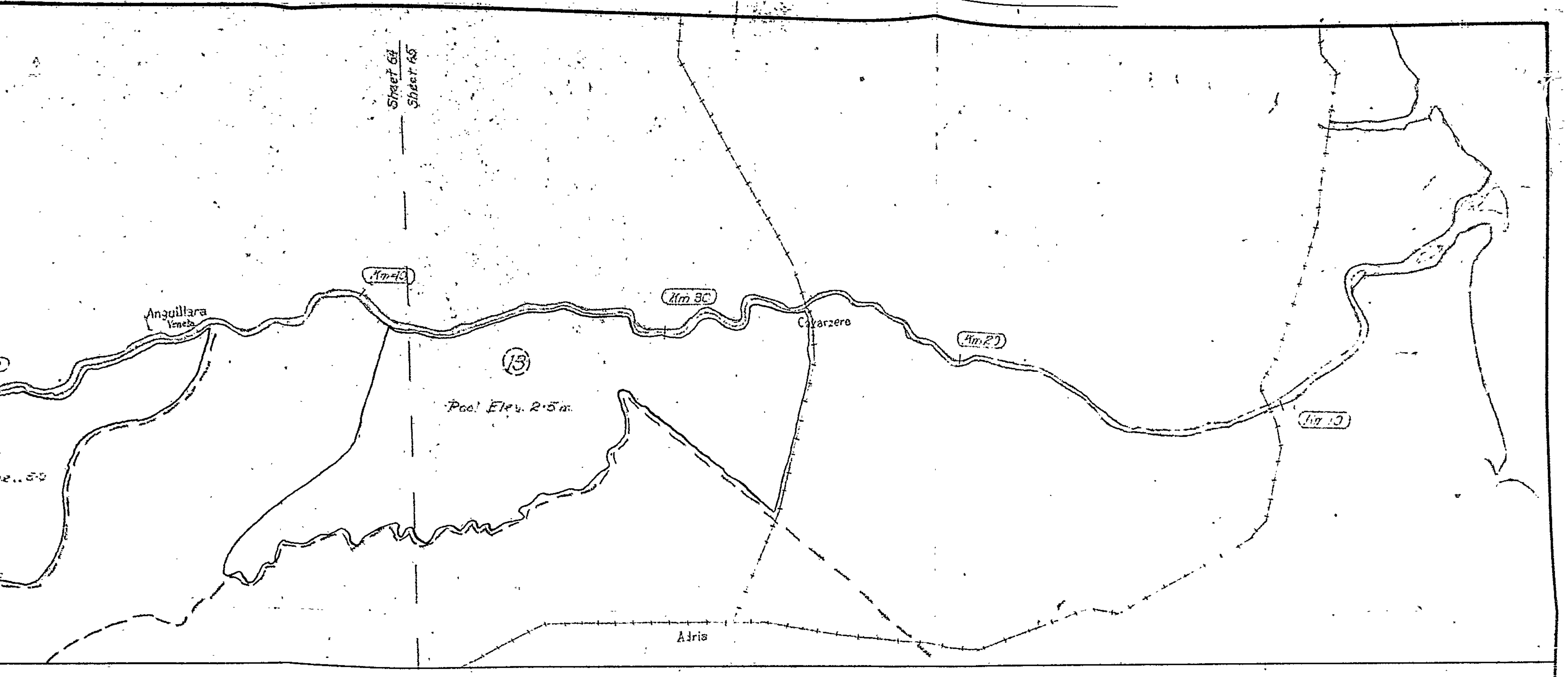
LEGEND

(8)	Still-Water Barrier Site No.
	Inundated Area
Km 20	River Km.
	RR Line
	Road Embankment
	Sheet Line (AMS 1:100,000 Series M-691)



SCALE
1: 100,000

VE
ST
WASH
Prep
Draw



3

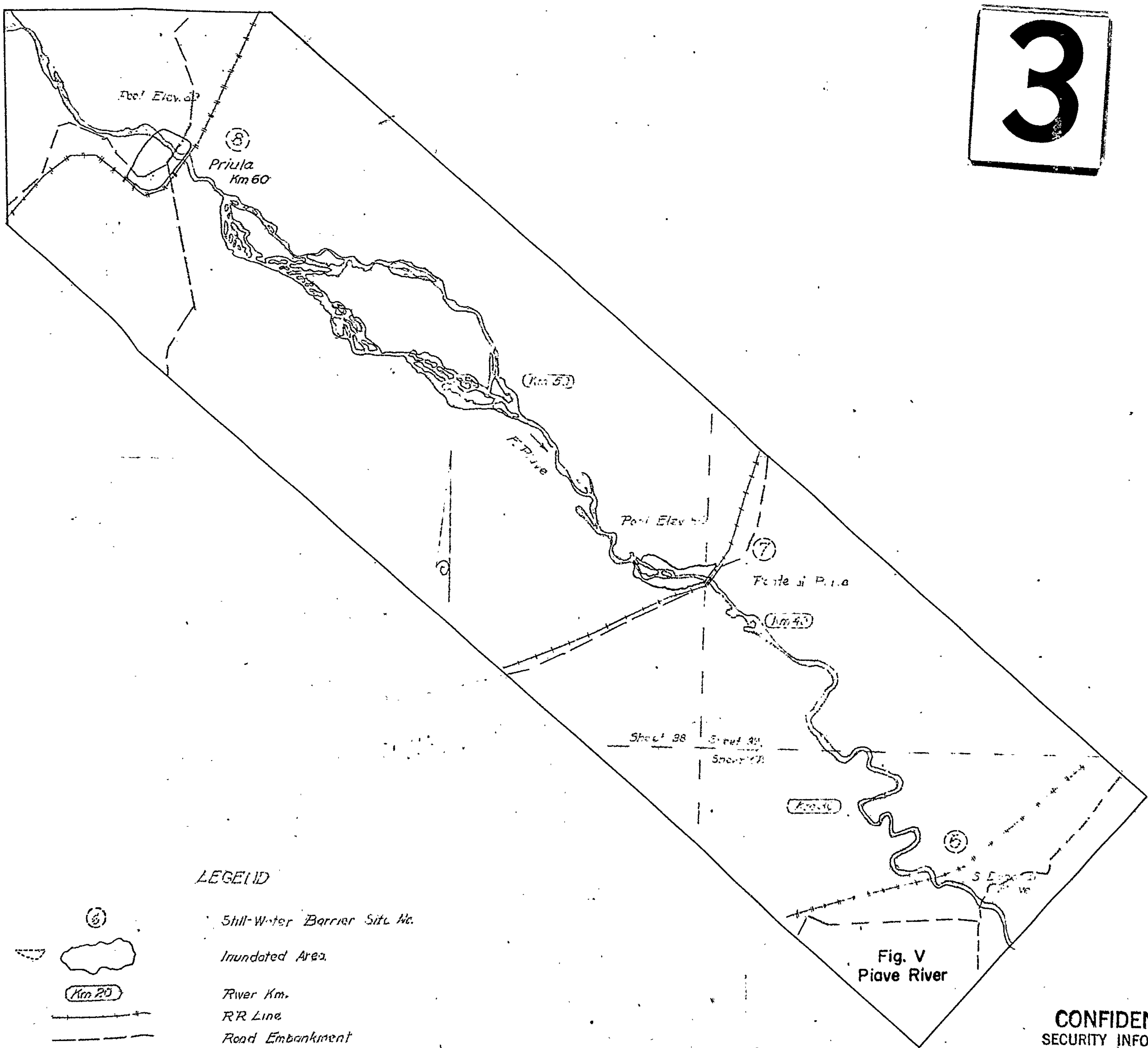


Fig. V
Piave River

LEGEND

(6)	Still-Water Barrier Site No.
	Inundated Area.
(Km 20)	River Km.
	RR Line
	Road Embankment
	Sheet Line (AMS 1/100,000 Series M-691)

0 — 10 Km.
0 — 6 Miles
SCALE
1: 100,000

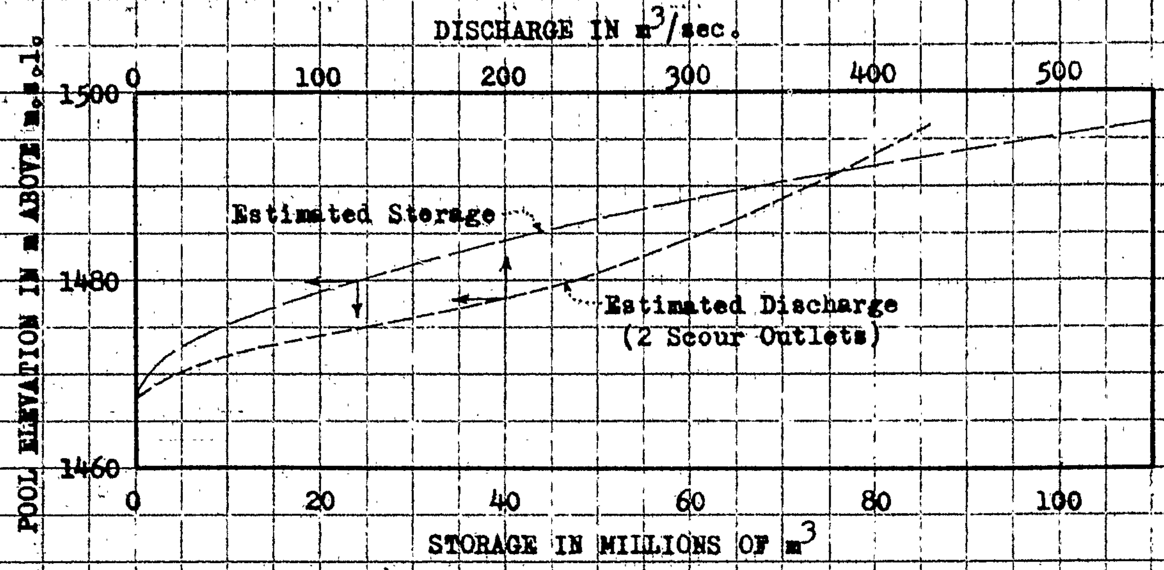
CONFIDENTIAL
SECURITY INFORMATION

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY
INUNDATION BY
STILLWATER BARRIERS

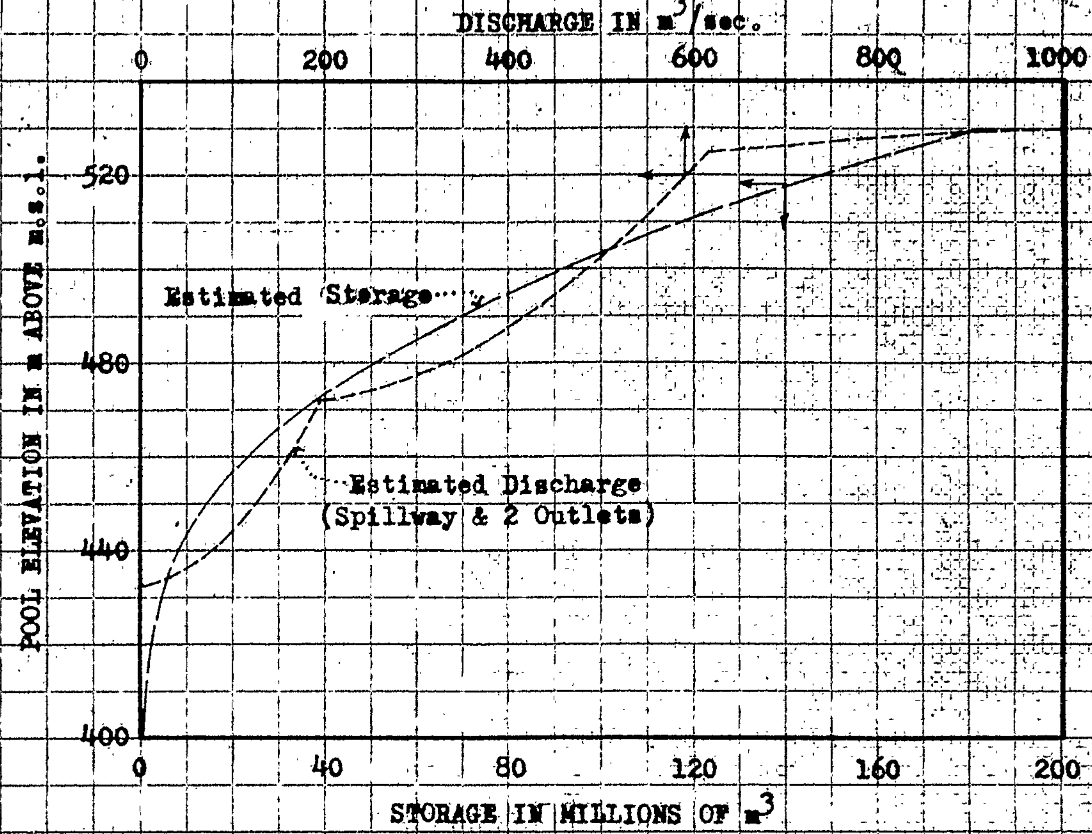
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by VB
Drawn by VB
Date July 1953

PLATE 11

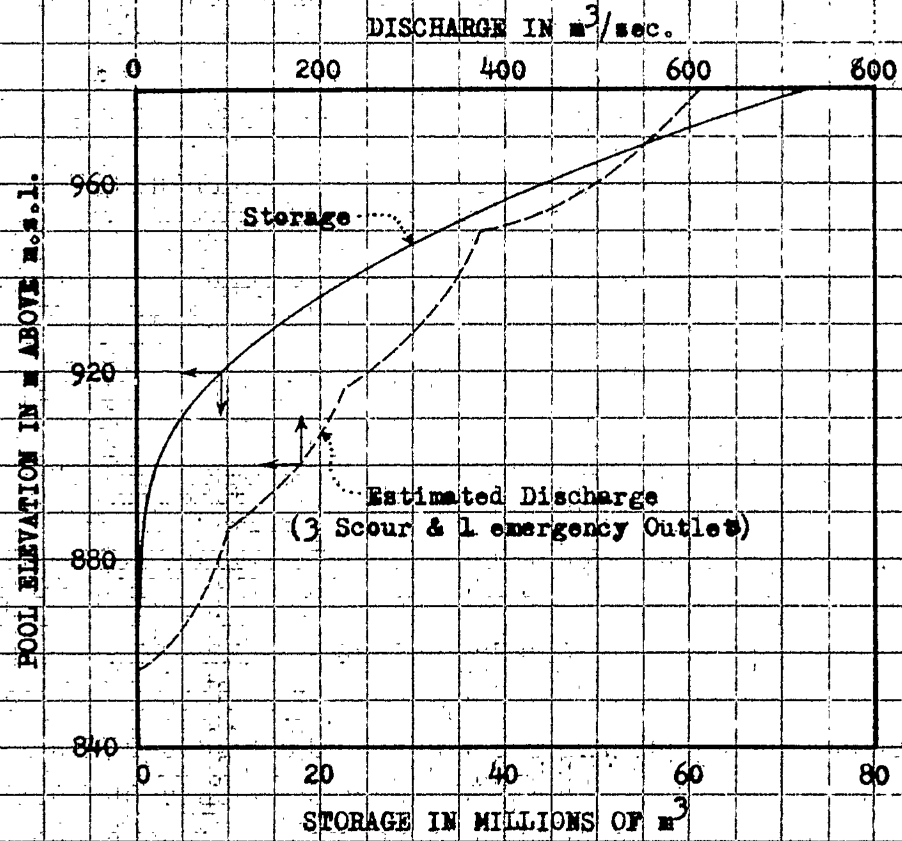
RESTRICTED
SECURITY INFORMATION



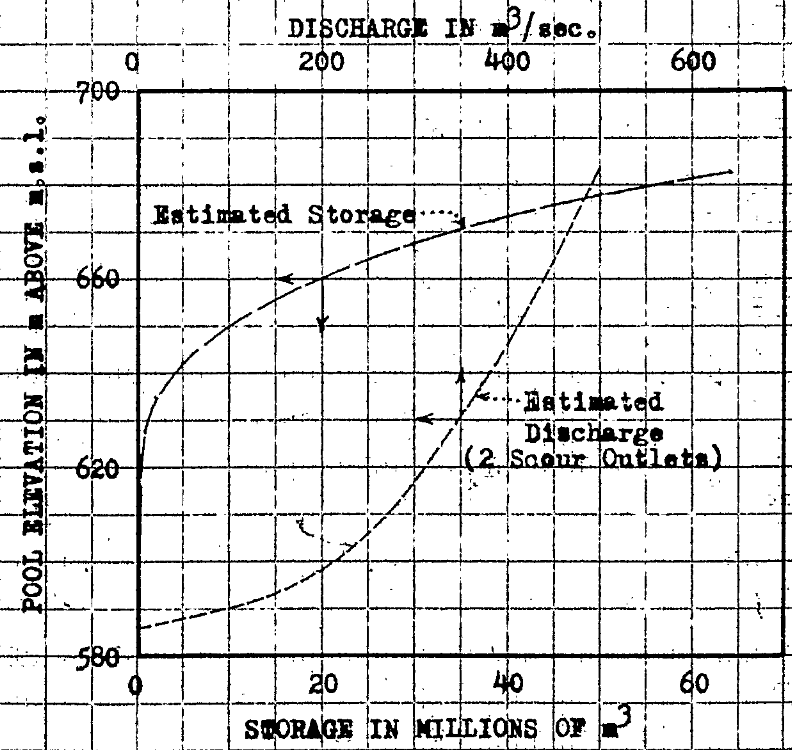
S. VALENTINO DAM R-22



S. GIUSTINA DAM R-28



LUMIEI DAM R-4



PIEVE DI CADORE DAM R-11

NOTE:
Curves shown are estimated.
See paragraphs 4-03b (2) & (3) and 4-03c.

RESTRICTED
SECURITY INFORMATION

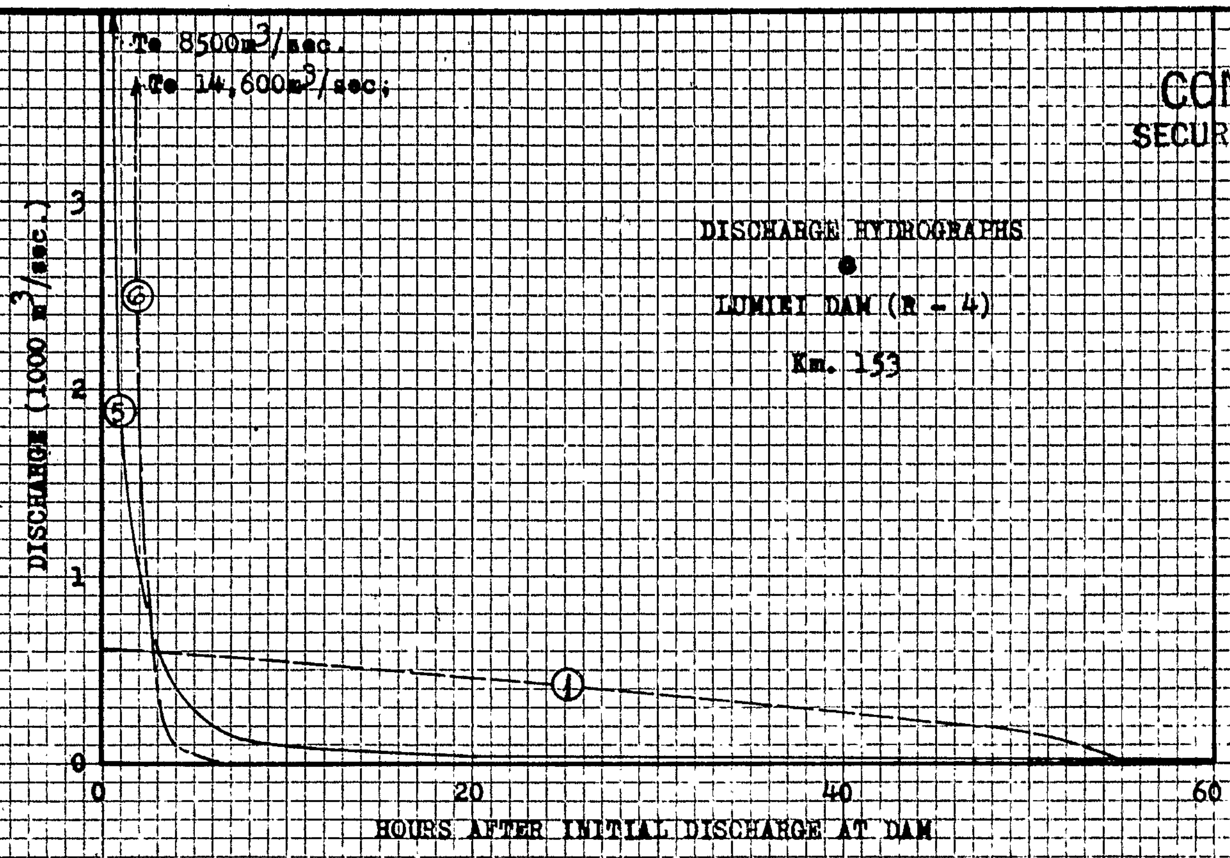
VENETIAN & FRIULI PLAINS OF NORTHEAST ITALY

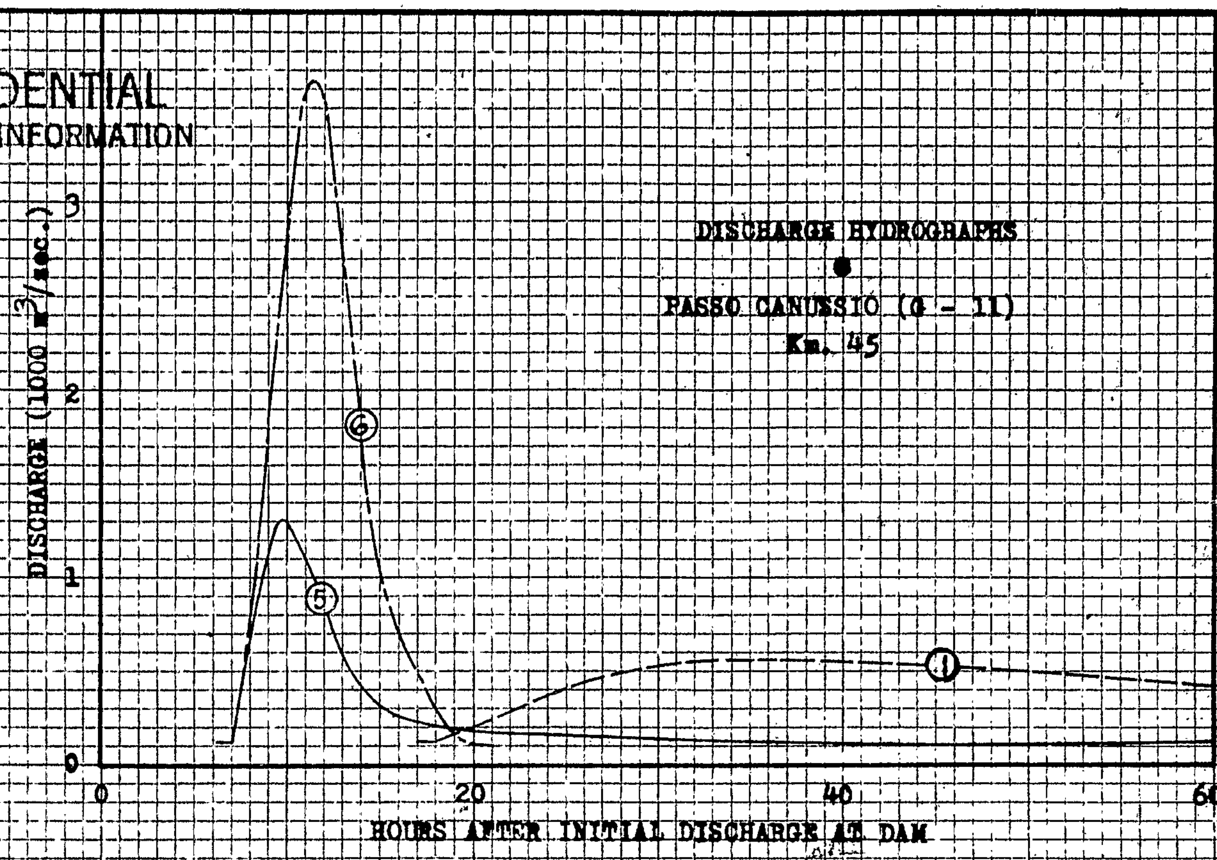
RESERVOIR STORAGE & DISCHARGE CURVES

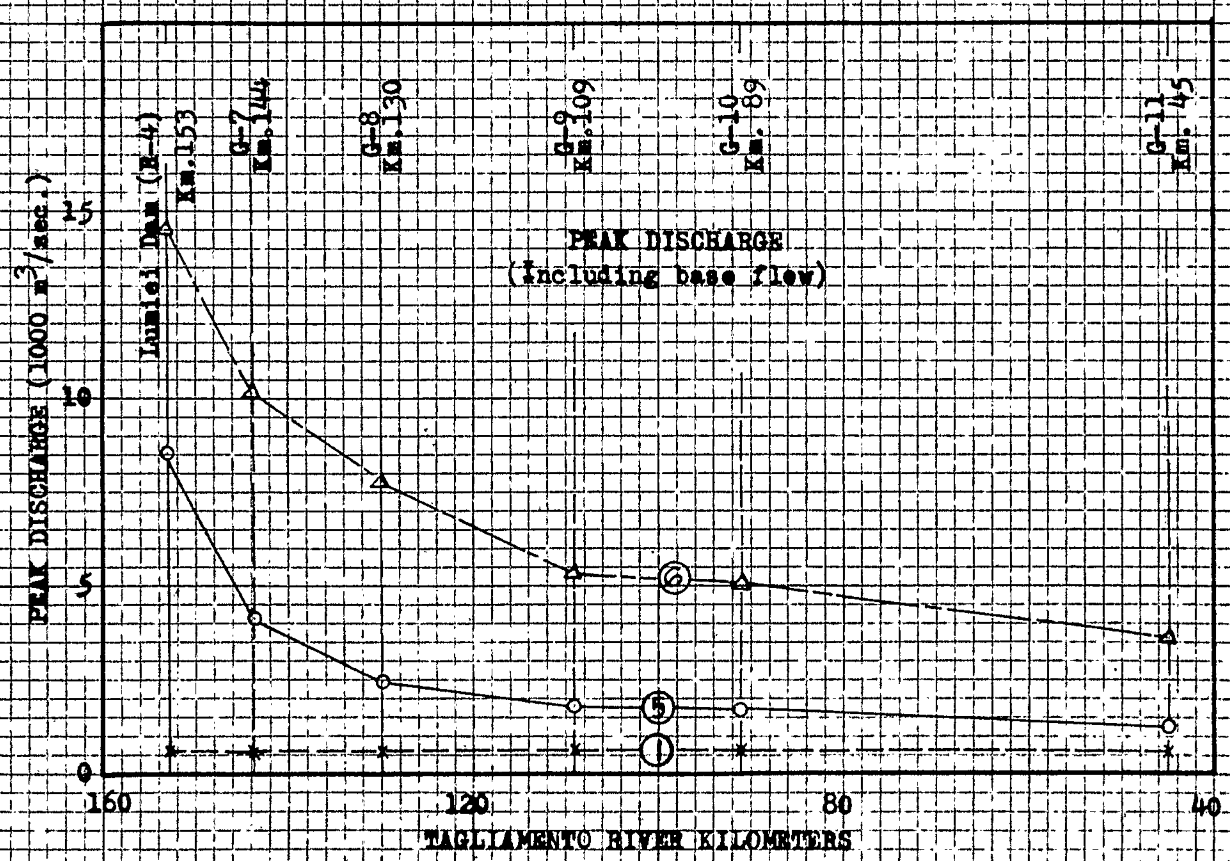
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by HAE Date July 1953
Drawn by JJH

PLATE 12

CONFIDENTIAL
SECURITY INFORMATION







DAM	ARTIFICIAL FLOOD NO.	TYPE OF DISCHARGE	PARAGRAPH
LUMIEI R-4	1	Outlets	4-03c & 4-03d (2)
	5	"Type A" Breach (Parabolic)	4-04c (2) & 4-04d (2)
	6	"Type B-1" Breach (Circular)	4-04c (3) & 4-04d (3)

NOTE: See Tables 6 & 7 for Summary of Effects.

CONFIDENTIAL
SECURITY INFORMATION

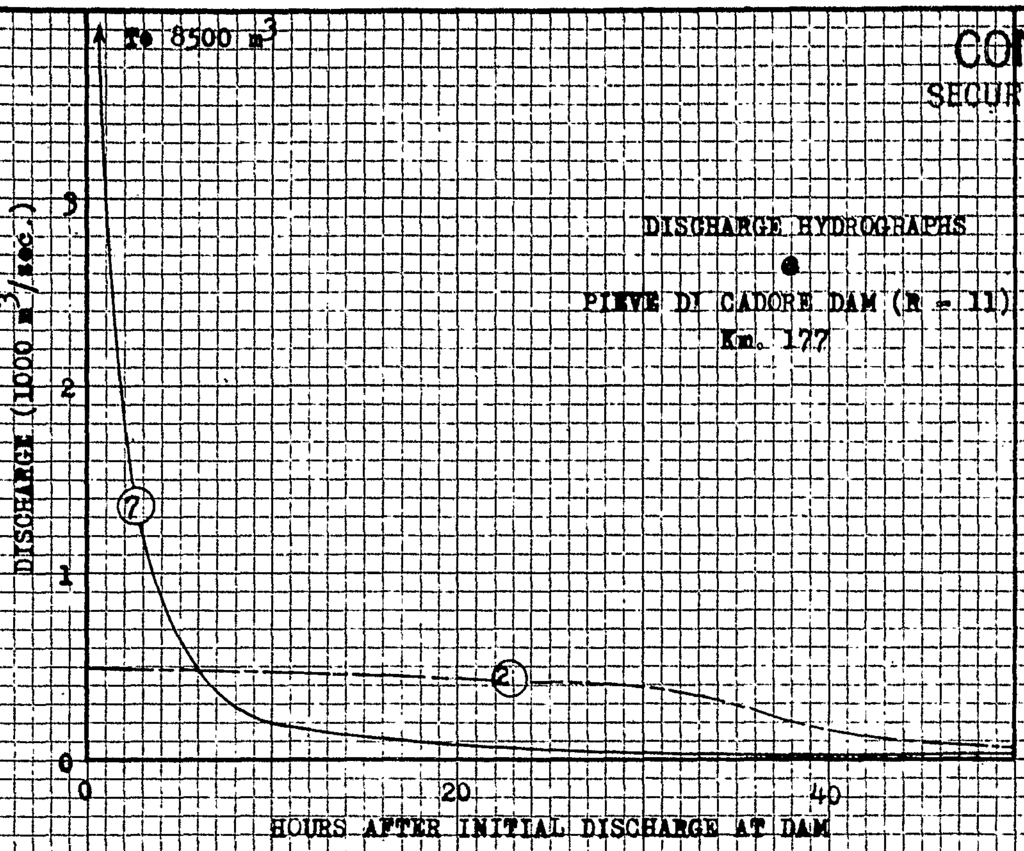
VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

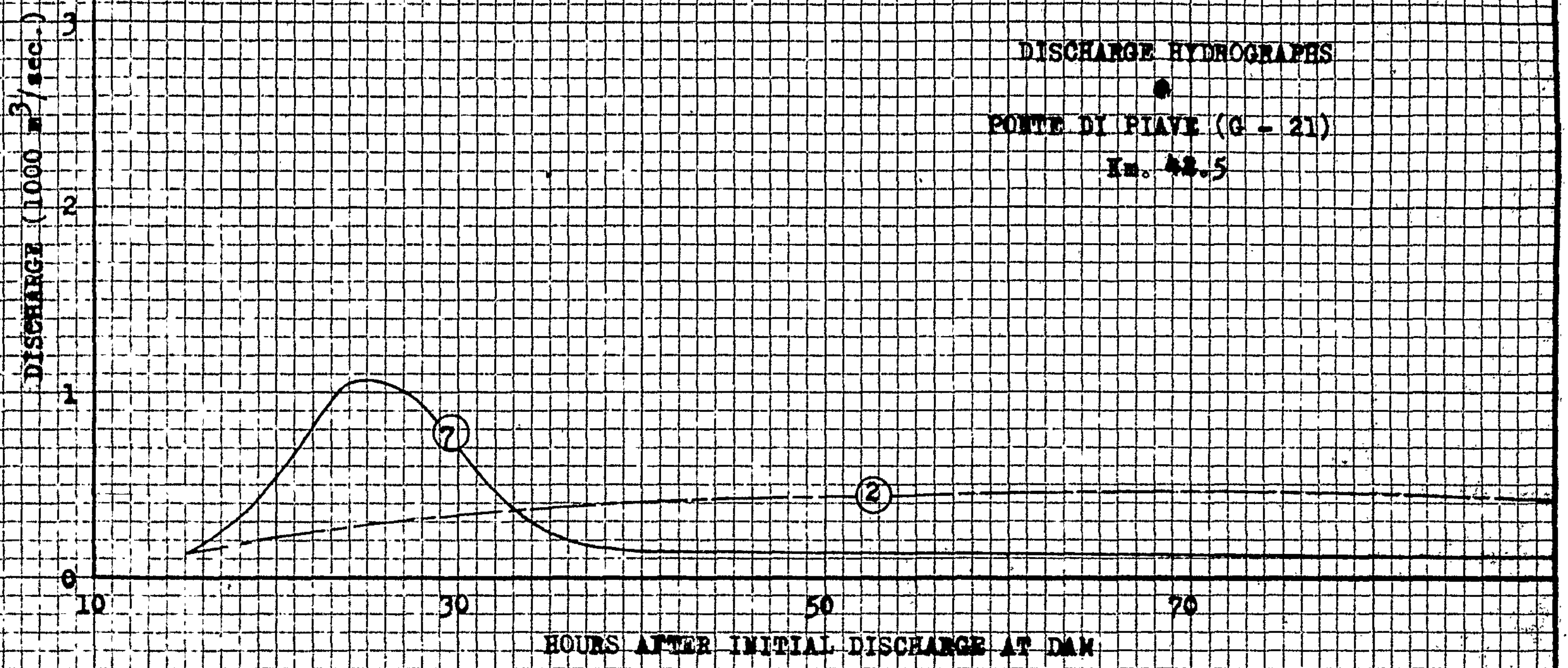
ARTIFICIAL FLOOD GRAPHS
TAGLIAMENTO RIVER

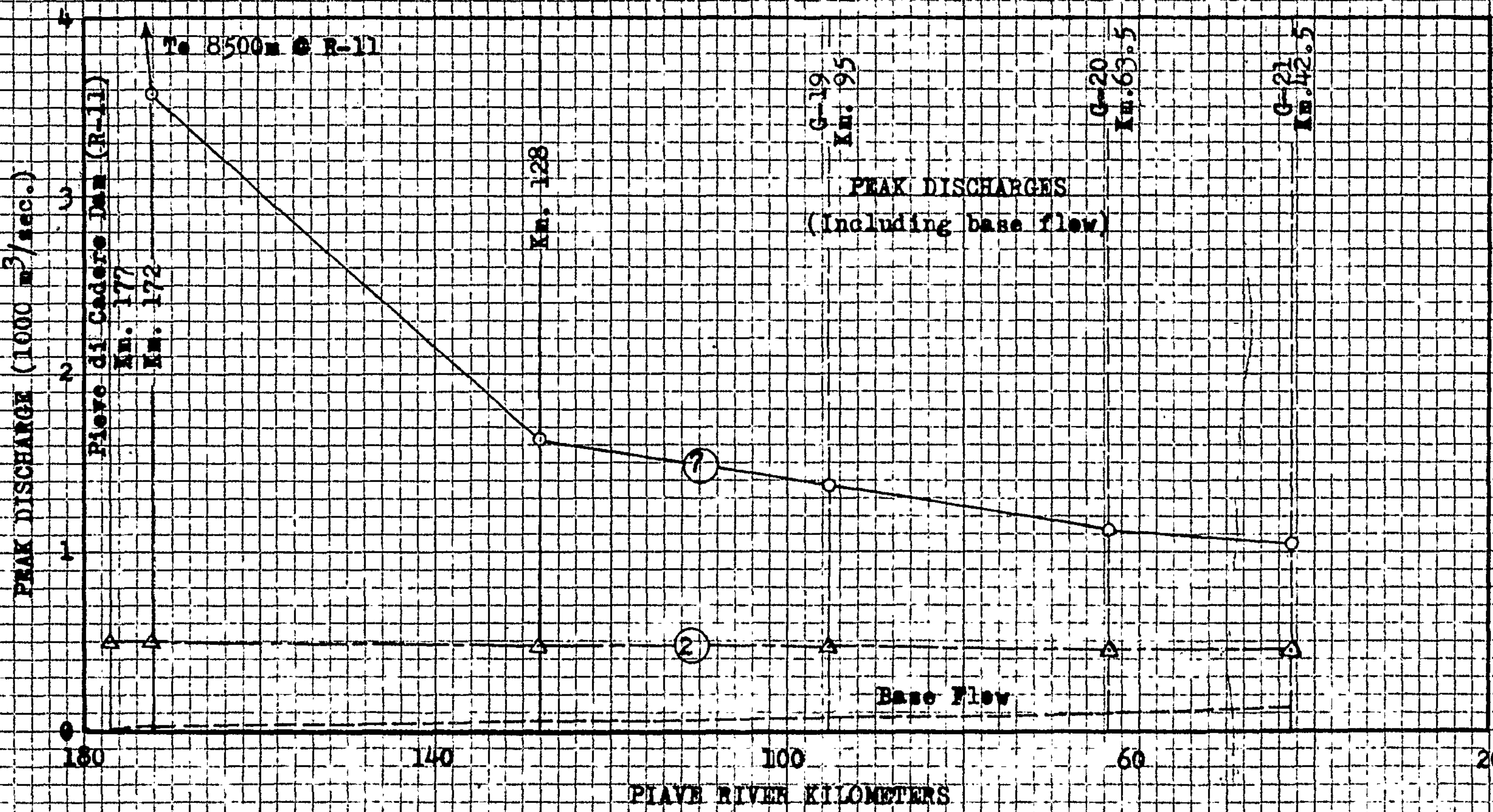
MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by F.B.B. Date July 1953
Drawn by J.J.H.

PLATE 13 a

CONFIDENTIAL
SECURITY INFORMATION







DAM	ARTIFICIAL FLOOD NO.	TYPE OF DISCHARGE	PARAGRAPH
Pieve di Cadore R-11	2	Outlets	4-03b & 4-03c (3)
	7	"Type A" Breach (Parabolic)	4-04c (2) & 4-04d (4)

NOTE: See Tables 6 & 7 for Summary of Effects.

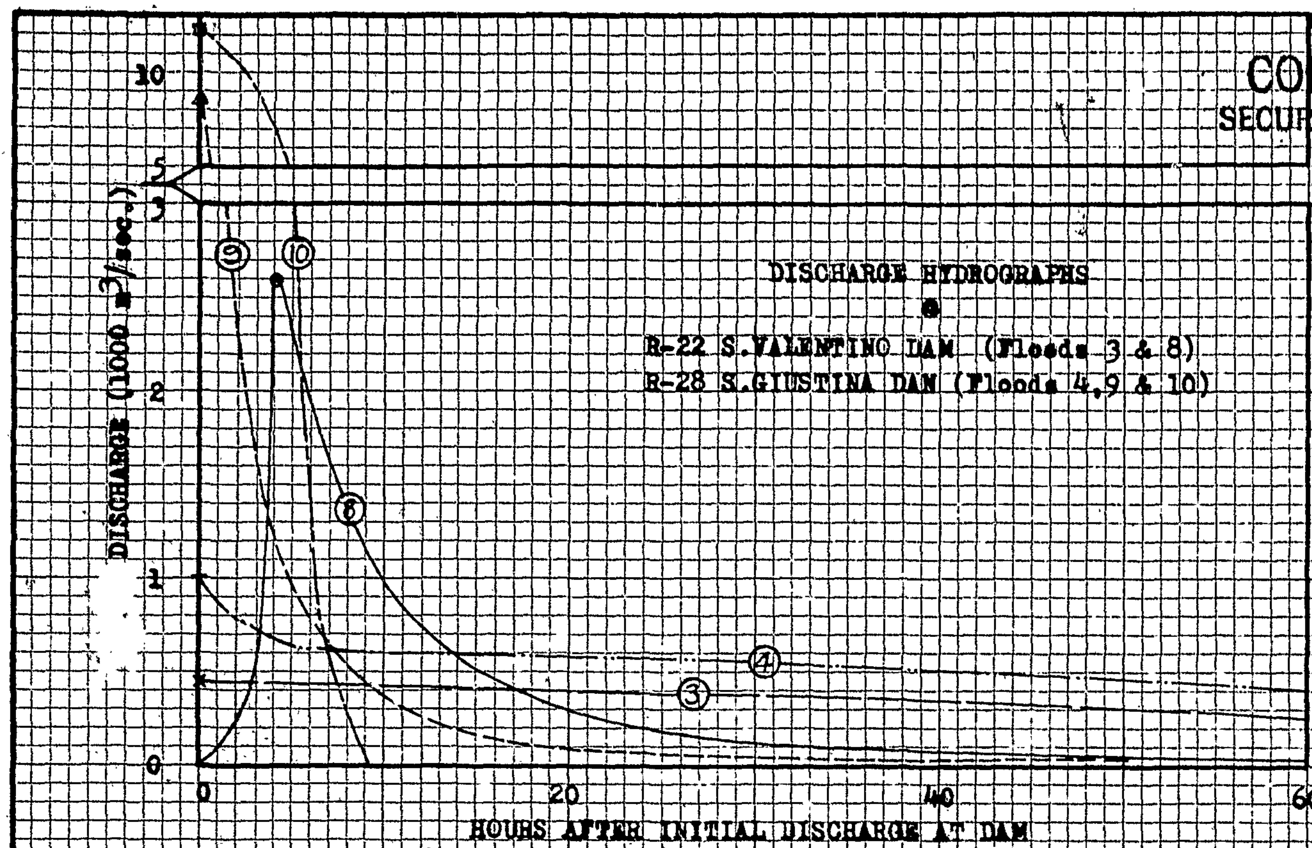
CONFIDENTIAL
SECURITY INFORMATION

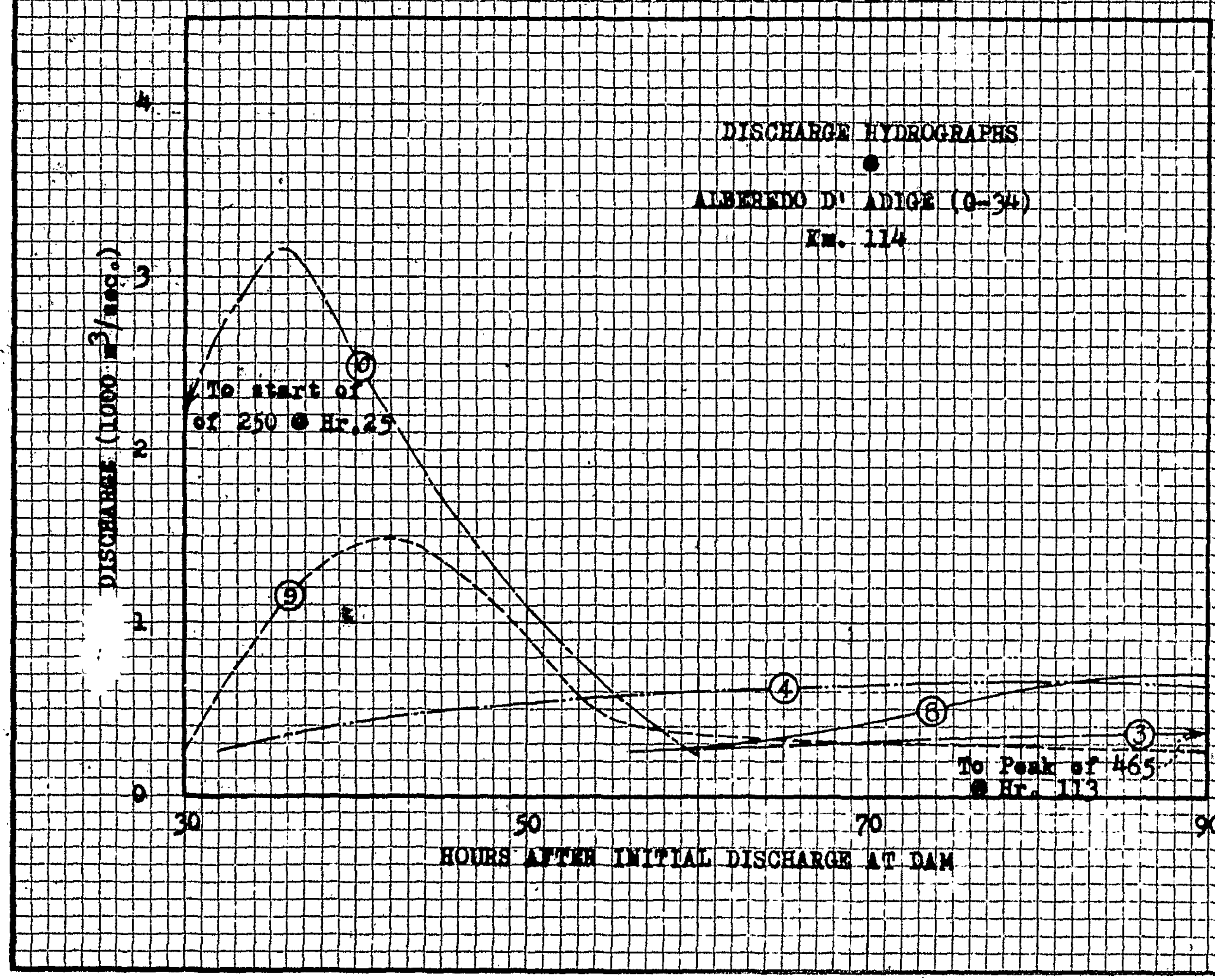
VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

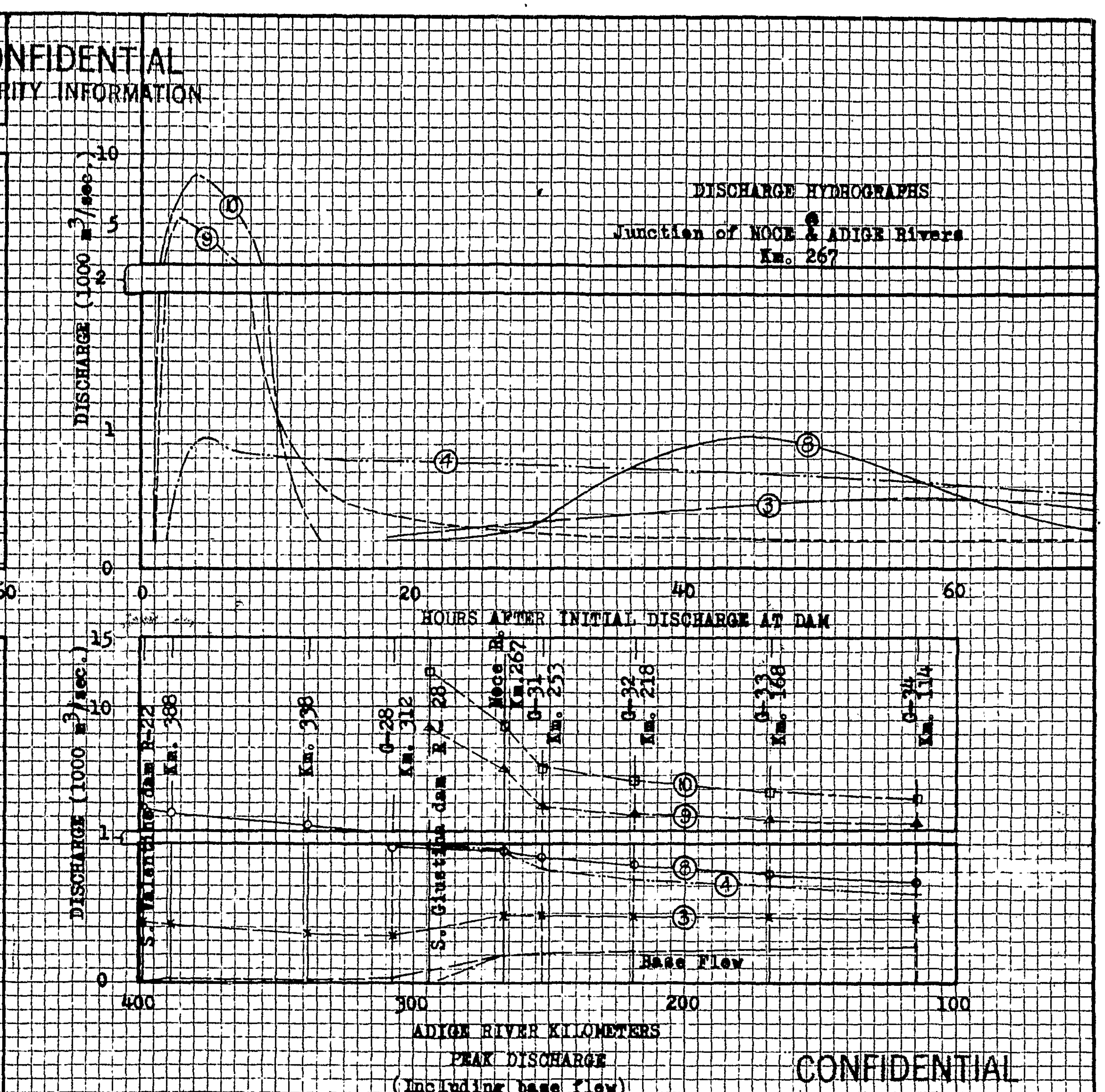
ARTIFICIAL FLOOD GRAPHS
PIAVE RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT, CORPS OF ENGINEERS
Prepared by FBB Date July 1953
Drawn by JJH

PLATE 13 b







DAM	ARTIFICIAL FLOOD NO.	TYPE OF DISCHARGE	PARAGRAPH
S.Valentino R-22	3	Outlets	4-03c & 4-03d (4)
	8	"Type C" Breach (Eroded Parabolic)	4-04c (5) & 4-04d (5)
S.Giustina R-28	4	Outlets	4-03c & 4-03d (5)
	5	"Type A" Breach (Parabolic)	4-04c (2) & 4-04d (6)
	10	"Type B-2" Breach (Circular)	4-04c (4) & 4-04d (7)

NOTE: See Tables 6 & 7 for Summary of Data.

VENETIAN & FRIULI PLAINS
OF NORTHEAST ITALY

ARTIFICIAL FLOOD GRAPHS
ADIGE RIVER

MILITARY HYDROLOGY R & D BRANCH
WASHINGTON DISTRICT CORPS OF ENGINEERS
Prepared by FBB Date July 1953
Drawn by LJH

PLATE 13 c

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE ON HYDRAULIC DEVELOPMENTS IN THE VENETIAN-FRIULI PLAINS

EXHIBIT A

ABSTRACTS OF TECHNICAL LITERATURE ON HYDRAULIC DEVELOPMENTS IN THE VENETIAN-FRIULI PLAINS

A-01. INTRODUCTION

a. This exhibit consists of abstracts of technical literature concerning the physical and hydrologic characteristics of the streams of the VENETIAN-FRIULI Plains of NORTHEAST ITALY and pertinent features of the hydroelectric power developments in the area. The information was obtained from American, Austrian, British, German, Italian, and Swiss technical literature. The sources are listed according to the Reference Numbers cited in the Bibliography following the text in the main body of this report. In selection of abstracted material, primary emphasis was placed upon hydraulic and hydrologic features that would be of use in the study covered by this report. Reference should be made to tho basic sources for other critical features, such as structural and electrical factors. The information available in the sources in many cases is incomplete. However, it is believed that the material presented in this exhibit would assist in determining the relative military-hydrology potentialities of the hydraulic developments now existing or proposed, within the region. In addition, this exhibit might be utilized to supplement information obtained from other sources and from field reconnaissance or to serve as a guido to indicate the nature and extent of desirable additional data to be supplied by further research or intelligence procurement.

b. Specific reference is also made to the general map, Plate 1 of the report, for locations of important elements and to Table 4 of the report for summarized pertinent data on hydroelectric structures. Serial numbers of hydroelectric power developments as shown in Table 4 and Plate 1 of the report are included in this exhibit to facilitate identification. The river kilometers cited in this exhibit correspond to the system used throughout the report and described in paragraph 1-04e of the text. A gazetteer of geographic names and locations appears as Exhibit B of the report.

A-02. HISTORICAL BACKROUND

a. This description covers the part of NORTH ITALY bounded on the east by the drainage basin of the ISONZO River, on the west by the ADIGE River, on the south by the ADRIATIC Sea (the natural outlet for runoff of this entire area), and on the north by the ALPS. The major part of the area is included within the Italian Province of VENEZIA. Besides the ADIGE and ISONZO Rivers

and their tributaries, this study includes the TAGLIAMENTO, PIAVE, LIVENZA, BRENTA, and BACCHIGLIONE Rivers and their tributaries.

b. It is important to refer to a few facts of recent history which may explain certain anomalities in the development of those rivers and the political struggle for their resources. Up to 1918, the end of World War I, jurisdiction over these rivers had been divided between AUSTRIA-HUNGARY and ITALY. The political boundary line followed very closely to the physidal boundary between the ALPINE MOUNTAINS and the VENETIAN PLAINS. The sources and upper reaches of the ADIGE, BACCHIGLIONE, BRENTA, PIAVE, and TAGLIAMENTO Rivers were located in the AUSTRIA-HUNGARIAN Province of SOUTH TYROL. Rapid discharge of flood water was the primary interest of the Austrian hydrographic authorities. The Italian territory along the lower reaches of these rivers was repeatedly subject to floods reaching catastrophic proportions in some years. The ISONZO River was an exception as, prior to 1918, it was confined entirely within AUSTRIA-HUNGARY. From 1915-1918, the ISONZO River marked an important battle line between the forces of ITALY and AUSTRIA.

c. As a result of World War I and the 1919 Treaty of Versailles, new Italian boundaries were drawn. The drainage areas of all these rivers were included within ITALY. Later, the Italian Government made a great effort to develop the upper reaches of these rivers by building hydroelectric power plants and other structures. This effort was interrupted by World War II but resumed again in 1945 as a result of U. S. economic aid granted to ITALY. Particular emphasis was placed upon development of hydroelectric power needed for ITALY'S industrialization because ITALY lacks coal.

d. As a result of World War II, Yugoslav Forces occupied the territory of the upper ISONZO River as far as the city of GORICE (GORIZIA). This annexation, however, is not internationally recognized "de jure" although we have to deal with it "de facto." Besides the ISONZO River, other rivers in this region also have served as important battle lines, particularly the PIAVE and TAGLIAMENTO Rivers in World War I.

A-03. GEOLOGY AND HYDROLOGY (Basis: References 15 & 73)

a. The area of the rivers under consideration is divided very distinctly into the mountainous Alpine part and into the VENETIAN PLAINS. The transition from highlands to lowlands is very abrupt (as shown by the map on p 258 of Reference 73 and by the physiographic diagram on Plate 2 of this report).

b. The mountains of the ADIGE Basin are marked in the east by the entrance pass at RESIA, where the source of the ADIGE

River is located. Towards the east lie the OEZTHAL-, STUBAI-, and ZILLER-ALPS with the famous BRENNER PASS along the AUSTRIAN border. Those mountain chains are mostly of Archean origin, and consist of schists, crystals, and granites. Many glaciers still exist in those mountains.

c. At the south, along the JUDICAIRE VALLEY, the dividing line between the Dinaric hard limestone of the EAST ALPS and the Archean massive formations in the WEST ALPS runs in a south-north direction towards MERANO. Between TRENTO and MERANO there extends a vast porphyritic plateau at 1200-1600 m above sea level, cut across by deep valleys and canyons. Near CIMA D'ASTA is the only granite and gneiss formation in the middle of an otherwise predominantly dolomitic region. Towards the east, around the MARMOLATE regions in the DOLOMITE ALPS, the source of the AVISIO and CORDEVOLE Rivers, the stratified limestone continues and is partly intruded by volcanic rocks such as basalt and porphyrite.

d. The VENETIAN PRE-ALPINE region, east of TRENTO, is marked by an Archean massive formation separated from the surrounding limestone ALPS. This area has many deep depressions such as the VAL SUGANA which contains the BRENTA River, and also lakes at LEVICO and GALDONAZZO. At the exit of the VAL SUGANA, the PRE-ALPS flatten in plateaus such as SETTE COMMUNI and GRAPA. The gorges of the BRENTA and PIAVE Rivers cut through these plateaus.

e. The SOUTHEAST ALPS or CARINTHIAN ALPS extend east from DOBBIACO (TOBLACH). They are of limestone and dolomitic substance, distinguished by longitudinal structure and straight valleys. Those mountains also form the AUSTRIAN border. Near DOBBIACO, in the valley of PUSTERIA, is the boundary between the RIENZA-ISARCO-ADIGE and the DRAU-DANUBE drainage basins. TARVISIO (748 m above sea level) in the eastern part of the CARINTHIAN ALPS, is another important dividing point, separating the valley of the FELLA River (a tributary of the TAGLIAMENTO River) and the SAVE (SAVA) River, a tributary of the DANUBE River.

f. The ISONZO River valley also can be reached from this point over a low pass. Farther east are the JULIAN ALPS along the Italian-Yugoslav border. Those are limestone mountains and have some very rugged ravines. At the south, the JULIAN ALPS join the KARST MOUNTAINS. The underground water of the "KARST" region drains into both the SAVE and ISONZO River basins. The steep slopes of the ALPS descending south into the VENETIAN PLAINS and the enormous volume of sediment carried by the rivers and streams originating in the high mountains of the north and flowing into the ADRIATIC SEA, have moulded the character of the vast, uninhabitable regions of the VENETIAN PLAINS known as "magradi" (poor land).

g. All the streams have a torrential character and thus require constant supervision because they often displace their beds and carry a considerably varying amount of flow. The TAGLIAMENTO reaches a 100 to 1 ratio between flood water and low water discharges.

h. The ITALIAN PLAINS emerged from the gulf of the ADRIATIC SEA at the end of the Tertiary Period. At the ALPINE border, ancient diluvial deposits predominate. The deposits change with depth into a sandy brownish clay known as "ferreto." At the exits of large valleys are enormous moraines in forms of "amphitheaters" or "fans" of concentric ridges such as are found on the TAGLIAMENTO River. Between the large valleys, there are numerous "torrential cones". Farther south, the ancient diluvium is covered by more recent diluvial deposits as a result of fluvio-glacier processes and the terrain slopes more gently towards the south. From this evolution came the great varieties of terrain relief characterized by lagoons, coastal dunes, and fluvial "watten".

i. The rivers were able to cut their beds deep in the diluvium in the lower reaches. Those cuts then became filled with clay. This accounts for the fact that in most cases the flow is above the surrounding terrain (e.g. the ADIGE River below VERONA) and large areas become flooded unless protected by high banks or other protective structures.

j. Important characteristics of the rivers follow:

River	Length km	Drainage area km^2	Discharges (m^3/sec) HHW	MW	LW
ISONZO	135	3,280	1,200	40	13
TAGLIAMENTO	170	2,590	1,500	80	50
PIAVE	220	4,100	3,000	60	40
BRENTA	174	2,310	1,035	140	25
BACCHIGLIONE	113	1,600	770	78	38
ADIGE	410	14,700	2,500	22	100

A-04. ISONZO RIVER

a. General Description. (Basis: Reference 74)

(1) The ISONZO (Yugoslav term is "SOČA") is 135 km long river originating in the JULIAN ALPS on MONTE JALLUZ, near TRICORNO and MANGART. Its drainage area is 3294 km^2. The main tributaries are: the IDRIA, TORRE, NATISONE, and the CARSO (VIPACCO).

(2) The abundant rainfall and snowfall amounts to

2500-3000 mm per year. Part runs off overground and part underground through the limestone or "karst" subsurface. The exact paths of this underground flow are often difficult to follow; therefore, the exact determination of drainage boundaries is difficult.

(3) The ISONZO VALLEY is characterized by a zig-zag course. The distance between the origin and mouth is 135 km along the course of the river, while the straight line distance is only 75 km. The upper part of the ISONZO VALLEY is relatively wide, particularly at the confluence of the CORITENZA at PLEZZO and also at TOLMINO where the basin was eroded by glacial action during the Quaternary Period. Between S. LUCIA and SALCANO, the flow is confined in a deep picturesque gorge. From there, the ISONZO River enters the FRIULIAN PLAINS, proceeding towards the ADRIATIC SEA along the "karst" slopes on the left.

b. Hydroelectric Development (Basis: Ref. 23 to 26, incl.)

(1) Prior to 1918 the ISONZO River was located in Austro-Hungarian territory. Between 1918-1945 the ISONZO River was located entirely on Italian territory and its development for hydroelectric power production was controlled by the Italian Government. The two major developments located in the ISONZO basin were completed shortly before the entrance of Italy into World War II in 1941. After 1945 the upper part of the ISONZO (above GORIZIA) was occupied by Yugoslavian Armed Forces and since then, this territory has been under control of the Yugoslav Government; however, the Italo-Yugoslav boundary is not yet internationally recognized. The two main hydroelectric power developments of the ISONZO (SOČA is the Yugoslav term) located in this region are consequently now under the control of Yugoslavia. These two major developments are:

(a) DOBLARI (DOBLAR is the Yugoslav term) Development.
  1. SOTTOSELLA (PODSELA) Dam
  2. DOBLARI (DOBLAR) Power Plant

(b) PLAVA (PLAVE) Development
  1. AIBA (AJBA) Dam and Intake Structure
  2. PLAVA Power Plant

c. SOTTOSELLA Dam (Serial No. R-1)
(Basis: References 23 to 26, inclusive)

(1) General. The dam was constructed between March 1937 and the autumn of 1939 by the Italian Government as part of the comprehensive electrification program of Italy. It is desig-

nated as Serial No. R-1 on the general map, Plate 1, and pertinent data are summarized in Table 4 of this report. The reservoir has a capacity of 6,400,000 m^3.

(2) Geologic and Hydrologic Conditions.

(a) The drainage area of the dam is 1290 km^2, of which approximately 20 percent consists of terrain which is nearly perfectly impermeable, such as sandstone, marl, and schist eruptive rocks. Seventy-four percent of the area is of less impermeable material, such as limestone, dolomites, brescia alluvions, and conglomerates. Annual rainfall of this area is very high, amounting to as much as 2300 mm in some years and, in some localities, up to 4700 mm. The low water discharge of the ISONZO at the dam site is 20-25 m^3/sec. The maximum flood flow recorded at the gaging station located a short distance downstream from the dam was 2200 m^3/sec. (The drainage area at that gage is 1357 km^2). The relief structures on the dam, however, were designed for 3000 m^3/sec based on statistical analytical calculations. The ISONZO valley at the location of the dam forms a very narrow and deep rocky gorge with 0.035 percent slope. Numerous "straits", some only 100 m apart, create an extremely rapid variation of river stages which, particularly at flood conditions, reach unusual proportions (e.g. 15-25 m per second at one cross-section *). The river bed width is 17 m at the elevation of the low water mark and 46 m at the elevation of the railroad. An important railroad line runs along the left bank 30-50 m above the low water mark of the river. Bedrock is found at 12-14 m beneath the low water mark. The alluvial layer is 8-10 m thick. Compactness and impermeability of the bedrock were examined prior to construction by means of extensive drilling. Solidification of the rock, in order to achieve complete impermeability, was achieved by a comprehensive net of injections at the cross-section of the dam. The injections reached deep into the surrounding terrain (see p 270 of Reference 24).

(3) The Main Dam Structure. Because of difficult terrain conditions, it was found necessary to build the dam on caisson foundations. The caisson, sunk by means of compressed air, was deposited on the solid rock approximately 16 m under the river bed at 105 m elevation above sea level. The floor of the sunken caisson was cleared of soft parts of rock to elevation 102.25. (This is the lowest point of the dam structure.) The caisson had horizontal dimensions of 29x15 m. The body of the dam was constructed on this caisson. The dam is a gravity-arch type constructed of reinforced concrete (see Figs. 2,3,4 and 6, pp 262-270 of Ref. 24).

* TRANSLATOR'S NOTE: This appears to be unusually high, but is an exact translation of original text.

The body of the dam has the following dimensions: -

Pool elevation	153.00 m above msl
Height of the dam	26.7 m
Angle of the circular arch	84 degrees
Thickness of the wall at the foot of the dam (el. 121.0 m)	6.0 m
Thickness at el. 143.5 m	4.0 m
Thickness at el. 143.5-147.7 m	5.0 m

(4) Auxiliary Dam Structure. The stream was dammed above the low water mark approximately 50 m upstream of the main dam site during the period of construction in order to divert river flow into the diversion tunnel. This diversion dam consists of gabions filled with gravel and other material from the river bed. Despite its primitive method of construction, the auxiliary dam proved satisfactory in fulfilling its functions and was retained after the completion of the main dam for purpose of stopping solid material moving with the flow. The crest of this dam was ultimately stabilized at 132 m elevation.

(5) Spillway and Outlets.

(a) The floodwater outlet structure consists of the following elements:

1. Two spillways each 1000 m^3/sec capacity; one on the left, the other on the right bank
2. An outlet at 127.95 m elevation
3. An outlet at the bottom of the reservoir, elevation 116.85 m

(b) The spillway on the right bank of the reservoir leads into the bypass gallery (diversion tunnel), which was used during the construction period and which was kept as a permanent part of the development. The bottom outlet of the reservoir also joins this diversion tunnel. The gallery is 144 m long and has a 54 m^2 cross-sectional area (see Fig. 5, Ref. 24). It was designed for 800 m^3/sec flow capacity; however, under actual conditions, when violent floods struck the development during the construction period, with an upper stage of 140.70 m and a lower of 128.50 m, the discharge was 1200 m^3/sec. The velocity of the flow in the normal cross-section of the tunnel was 22.5 m/sec and the tailwater level 1.50 m above the top of the outlet opening. The entire flood carried 1800 m^3/sec (p 304, Ref. 23). The entrances of both spillways are provided with 3-part gates which may be lifted above the pool stage elevation of 153 m. The spillway crest is at elevation 141 m. The upper part of the gate is a flap,

hinged horizontally to the middle leaf, and provides for 2.80 m height of closure between elevation 150.20 and 153 m. The middle part of the gate is 5.60 m high, and its lower edge closes at elevation 144.60. The lowest part of the gate is 3.60 m high and closes the opening between 144.60 m and 141.0 m which is the elevation of the crest of the spillway.

(c) The bottom and middle outlets are equipped with gates operated from a platform at 154.0 m (see Fig. 5, Ref. 24). The bottom outlet conduit is 51.00 m long, on 0.057 percent gradient, and of semi-circular cross-section equipped with 4x4 m gates. The middle outlet conduit, which starts at elevation 127.95 m and ends at 123.95, is 81.60 m long, and is also of semi-circular cross-section equipped with 3.4x3.4 m gates.

(6) Power Plant Conduit. The intake structure from the reservoir of the dam into the pressure tunnel (see Figs. 2b and 8, p 218, Ref. 24) is equipped with 2 gates: one fixed, and the other movable. The 5x5 m double gates are power operated from the platform at 160.0 m elevation and serve to close the tunnel. At approximately 260 m from the entrance, the tunnel crosses a tributary of the ISONZO River by means of an aqueduct. The normal clear cross-section of the tunnel is 5.6 m diameter. Its total length between SOTTOSELLA (PODSELA) weir and AIBA power plant is 3785 m; and it has 90 m^3/sec flow capacity. Along its entire length it is drilled in the rock and lined with 0.17-1.23 m thick concrete and reinforced by steel in places where required.

(7) DOBLARI Power Plant. The SOTTOSELLA (PODSELA) Dam pressure tunnel leads into a surge chamber at the DOBLARI Power Plant (see Fig. 9, p 308 of Ref. 23 and p 21, Fig. 2 of Ref. 26). This type of surge chamber and shaft was developed in order to minimize the very rapid variation of hydraulic head, due to sudden changes in the ISONZO flow and thus to avoid adverse effects on the turbines. The gross hydraulic head varies between 47 and 29 m (153 and 148 m upper and 106 and 119 m tailwater elevation). The mean hydraulic head of 43 m is used for calculation of power. The flow from the surge tank is directed to 3 vertical turbines, each having 30 m^3/sec flow and 15,000 HP power capacity. The total capacity of the power plant is 33,000 KW and the annual output is 150 million KWH. The power operated level of the turbines is at elevation 107.50 m. The underground character of the power plant and its elevation with regard to the tailwater level in the river required a special construction of the draft tubes. The draft tube of the turbines leading into the tailrace conduit is 8 m long, of semi-circular cross-section and of slightly arched bottom, 5.0 m wide and 3.75 m high. Behind each draft tube is a regulation chamber 7.0 m wide and 13.0 m high with a ventilating shaft. Each of these regulating chambers has 1800 m^3 of partial volume. They

serve for damponing of the tailflow in the river. The axes of the turbines are at 107.50 m, which is 13.0 m under the floor of the machine house and only 1.50 m above the level of the river at elevation 106.00 m. The power plant is completely underground with a minimum 20 m of rock covering.

d. PLAVA Development.

(1) General. The Italian name of this development is PLAVA, the Yugoslav name is PLAVE. It was built by the Italian Government in the period from 1938 to 1941 and was taken over by Yugoslavia in 1945. It is now operated by the latter government. This development consists of:

(a) AIBA (AJBA) Weir
(b) PLAVA Power Plant

(2) AIBA Weir (Serial No. R-2)
(Basis: References 23 & 26)

(a) The 52.50 m long weir across the ISONZO River at AIBA consists of both movable and fixed parts. It elevates the flow of the river to 106 m, the normal stage of the upper pool. The utilized storage amounts to 1.3 km^3. The weir has 5 openings, each 8.0 m wide; and 4 midstream pillars : 2 at 4.0 m, 1 at 3.5 m and 1 at 1.0 m wide.

(b) Adjacent to the left bank are 2 fixed weirs, each 8.0 m wide, separated by a 1.0 m wide pillar. Their crest is at the normal pool elevation of 106 m.

(c) The two middle openings have their sills at 96.0 m elevation. Lifting gates with an automatic flap, turning on a horizontal axis hinged to the main gate structure, regulate the flow between 103.5 and 106.0 m. The opening on the right bank has a sill elevation of 94.0 m and is equipped with a double sluice gate which permits the scouring of solid material accumulated behind the weir.

(d) On the right bank the weir extends into the intake structure providing for the entrance into the power conduits. The flow is diverted through a regulating gate into a sand removal channel, prior to entry into the pressure tunnel. The tunnel is 6700 m long, of 6.3 m diameter circular cross-section, drilled into rock and lined with concrete.

(3) The PLAVA Power Plant. The power plant is completely underground and is equipped with 2 Kaplan turbines each 15,000 KW capacity. The annual output is 90 million KWH.

A-05. TAGLIAMENTO RIVER
(Basis: Reference 29-37, inclusive)

a. General Description.

(1) The TAGLIAMENTO River, a torrential stream of the FRIULIAN PLAIN, is 170 km long and has a drainage area of 2700 km^2. Its source is at FORNI DI SOPRA near LORENZAGA and lies 1195 m above sea level.

(2) The river flows east in a longitudinal valley separating the CARNIAN ALPS of impermeable clay schists of Paleozoic origin, from the FRIULIAN PRE-ALPS of permeable and semi-permeable limestone and dolomitic limestone, sand and conglomerates, interspersed partly by clay. It has numerous tributaries in this stretch. The left side tributaries such as LUMIEI, DEGANO, BUT, and FELLA in the upper reaches supply much more flow than the right side tributaries. In this part of the course originates the torrential character of the river; because, in a fairly short distance is concentrated the steep floodwater from the high CARNIAN ALPS and their lakes. All these tributaries carry much limestone dolomitic detritus which descends into the valley of the main stream and forms characteristic cones.

(3) Below the junction with the FELLA River the valley widens. The valley floor is typically wrinkled as the result of Quaternian glacier activities. The bed is filled with gravel and sediments of great variety through which the stream works its way and partly infiltrates because of the permeable character of the valley floor. Near VENZONE, there is a large morainal "amphitheater" which was formed across an old permeable alluvial plain, as the result of loss of flow in its vicinity. At low water, the bed in this part is often entirely dry. The only tributary on the right side, the ARZINO, supplies the main part of the surface flow, as the main flow infiltrates below its own alluvial deposits. These deposits enlarge the bed and also create great water losses.

(4) Below the junction with the ARZINO, the TAGLIAMENTO River flows for 65 km through the plains, entering the ADRIATIC SEA through the LAGUNA DI MARANO. Beginning at CASARSA, the plains are characterized by their abundant underground water supply of unknown origin.

(5) Numerous small streams in the immediate vicinity of the TAGLIAMENTO join independently into the LAGUNA DI MARANO. Among them the STELLA River is the most important. These streams are fed largely by underground water accumulated in this depressed region. The mean flow of the STELLA River is 50 m^3/sec.

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b. Hydroelectric Developments. The major existing development in the TAGLIAMENTO River basin is the LUMIEI Development consisting of:

(1) LUMIEI Dam and Reservoir
(2) CORTINA D'AMPEZZO Power Plant

c. LUMIEI Dam (Serial No. R-4)
(Basis: References 29 - 37, 79)

(1) General.

(a) The LUMIEI Dam is located on the LUMIEI River, a left-bank tributary of the TAGLIAMENTO, in the region called "MAINA SAURIS". Here, the bed of the LUMIEI changes from lower Triassic and upper Permian strata to the tough dolomitic limestone of the middle Triassic Period. A rocky gorge with almost vertical sides was eroded through the limestone. The construction of the dam began in 1941 and continued to 1943. After interruption because of the war, construction was resumed in 1946 and the dam was completed in 1948. The 81 km^2 drainage area of the LUMIEI at the dam site was increased by adding to it the flow of the ALTO TAGLIAMENTO. This additional flow is transferred directly into the LUMIEI Reservoir by a conduit. The total drainage area so utilized is 58 km^2. Prior to construction, the whole area of the dam contact with the rock at the bottom and sides of the gorge was solidified by deep injections, to avoid any seepage from the reservoir.

(2) Dam Structure. The concrete structure of the dam is of a so-called "cupola" type, the dam being curved horizontally as well as vertically. (See Figs. II & V on Plate 8a of this report). The "cupola" wall rests on a 15.87 m thick foundation which plugs the lowest part of the gorge. Despite the favorable geologic conditions, the right wing of the dam was imbedded in the excavated side of the gorge in order to create a symmetrical shape for the dam. The main part of the dam is of trapezoidal shape and separated from the foundations and also from the sides by a joint. The dam is constructed of concrete blocks separated by vertical joints, sealed by a special process.

Portinent dam data are:

Length of the dam at crest	138.4 m
Radius of the crest	78.1 m
Chord length	122.8 m
Height of the structure	136.4 m
Thickness at the crest	3.49 m
Thickness at the foot	13.68 m
Crest elevation	984.30 m (msl)
Maximum surface elevation	982.0 m (msl)
Normal surface elevation	980.0 m (msl)
Minimum surface elevation	905.0 m (msl)
Drainage area	81.0 km^2
Storage capacity (utilized)	70.0 million m^3
Storage capacity (total)	72.8 million m^3
Area of the storage lake	164.0 hectares

(3) Spillway. On top of the dam is a spillway consisting of 5 openings each 10 m wide. The overflow crest is at 980.00 m elevation. The spillway is capable of carrying the flood flow of approximately 250 m^3/sec with a 2.0 m head on the crest.

(4) Scour Tunnels.

(a) Bottom, middle, and top outlets or so-called "scour tunnels" are located on the left side and provide for the emergency flood flow. (See Fig. I on Plate 8a of this report.) The bottom outlet has its intake at elevation 886.90 m, the regulating valve at elevation 886.17 m and the exit at elevation 885.17 m. The outlet is 112 m long and has a circular cross-section of 4.2 m diameter. At certain points it narrows to a rectangular section 1.60x2.40 m. In this section are 2 sluice valves: one for holding purposes only, while the other can be adjusted under load. In the joint between the two sections are embedded the two outlets of the air duct intended to aerate the conduit to prevent cavitation. The capacity of this outlet is 140 m^3/sec.

(b) The middle outlet has corresponding elevations of 917.33, 916.65, and 915.76 m. It is similarly provided with a sluice and has the same characteristics as the bottom tunnel except that the diameter is 3.70 m, and the length is 99 m. This outlet has a capacity of 114 m^3/sec.

(c) The top outlet has corresponding elevations of 947.94, 947.20, and 946.42 m, respectively. The diameter is 4.20 m and the rectangular portion measures 2.30x3.0 m. Again, one of those sluice valves is for holding purposes, while the other can be adjusted under load. The length of this tunnel is

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91 m. All three outlets can carry a total flow of 400 m^3/sec.

(d) These three scour tunnels have an access gallery consisting of a shaft 3.05x5.70 m and 111 m deep divided into three compartments. One compartment has an iron staircase, the second accomodates a hoist with 30 metric tons capacity, and the third acts as an air vent. From the bottom of this shaft, there is an underground passage which leads to the river bank and a closed passage leads to the intake valve chamber from the right bank. All controls, mechanism and apparatus are arranged in a central control chamber situated at the top of the shaft. (See Fig. III on Plate 8a of this report.

(5) Emergency Outlet. In addition to the scour tunnels, there is an emergency outlet in the diversion tunnel at elevation 857.16 m consisting of a section of metal pipe (See Fig. IV on Plate 8a). This outlet is located in line with the dam and is closed by a metal cover which can be operated after the manner of a valve. In extreme emergency the reservoir can be emptied quickly by blowing the cover with an explosive charge placed in an appropriate chamber.

(6) Power Tunnel.

(a) The power tunnel has a capacity of 16.4 m^3/sec. The intake is provided with a coarse rectangular trash-rack mounted on a wheeled frame which is raised and lowered on a convex track by means of two cables and a winch. The trash-rack has overall dimensions of 6x4.50 m and is fitted with bars 25mm thick and spaced 146 mm apart. This coarse trash-rack is followed by a second finer screen fitted with bars 15 mm thick spaced at intervals of 45 mm.

(b) At the outfall end, the tunnel leads to a fabricated pipe 2.40 m in diameter and 34.20 m long. A butterfly valve is situated in a chamber accessible from outside through an underground passage. This valve can either be remotely controlled or operated on site by means of an oil servo-motor; it is also fitted with an automatic closing device (functioning in 40 seconds in the event that an excessive velocity of flow would develop). Downstream from the butterfly valve is a float valve for the air inlet. The chamber containing this apparatus is 9 m long by 7.20 m wide and is fitted with a water-tight partition so that the apparatus can be operated in the event of flooding.

(c) The tunnel from the reservoir is 4168 m long and has a 2.60 m diameter. At 4112 m from the outlet is the surge chamber. The average gradient is 0.518 percent but varies according to the sections for constructional reasons. The nature

of the rock to be traversed was in parts unfavorable for a tunnel subjected to strong pressure. The strata traversed included a massive Triassic limestone and a short length (about 10 m) of exceptionally hard green siliceous sandstone and a nodular limestone of varying characteristics. Finally, "Werfen" sands were intersected with grey limestone and lengths of decayed Permian dolomite. It was thus necessary to use different forms of lining for the various sections. Where the rock was strong, a simple concrete lining was inserted; in the weaker sections, rings of gunite in one or more layers reinforced with steel rings were used. These rings were of varying diameters and thicknesses and were used in conjunction with a meshwork of steel reinforcement. Where the rock was reasonably strong, the metal netting was used in the concrete without the steel rings.

(7) Surge Chamber. This consists of a vertical shaft 4.00 m in diameter and having two expansion chambers: the lower of which is of circular section, 2.60 m in diameter and 122.85 m long; the other, higher up, is of polycentric section and measures 6.50 by 7.65 m by 25 m long. The nature of the rock was rather poor and abundant transverse reinforcement was necessary, together with considerable longitudinal reinforcement to form bridges of solid support between one point and another.

d. CORTINA D'AMPEZZO Power Plant.

(1) An open-air steel pipeline runs to elevation 646 m, at which point it passes into a vertical shaft 100.96 m in depth, excavated in the rock until it connects with a section at 45° leading to the three-branched distributor. The pipe is of welded sheet steel with riveted joints and was tested up to a pressure of 24.5 atmospheres. The total length, including the distributor, is 766 m.

(2) The power station is excavated in the interior of the mountain near AMPEZZO CARNICO, from which point it can be reached by a road 1.5 km long, built for the purpose. The power plant capacity as installed totals 58,500 KW, divided into three 19,500 KW units. Each unit consists of a horizontal shaft alternator mounted between two Pelton wheels. The generated voltage is 10,000 volts. In the basement is a repair shop, a room containing the switchgear and a storeroom; the transformer cubicles are in the open. Three transformers, each rated at 26,000 KVA, step up the generated voltage to 135 KV for overhead transmission.

(3) The machine room is 51.55 m long and 12 m wide, excluding the walls. Although the rock does not exert

pressure through swelling, there are planes of fracture and slick-sided surfaces which give rise to pressures which were sufficient to make the constructional work difficult. The poor conditions in the rock mass necessitated a concrete pillar structure with reinforced buttresses and intermediate relieving arches. To connect the reinforced pilasters with the vault, which had already been erected, deep incisions were made in the rock walls of the vault to accomodate those extensions of the pillar reinforcement.

(4) The discharge channel is 234 m long, 3.50 m in diameter and of roughly circular section. Where it enters the LUMIEI River, the channel can be closed by a sluice which has the double purpose of permitting the discharge of the water from the proposed plant at VILLA SANTINA, and of preventing water from flowing into the basement of the power station in the event of exceptional floods.

(5) The shafts of the Pelton turbines are situated at elevation 502.825 m; therefore, the gross head varies from a maximum of 477 to a minimum of 402 m, the average head being about 450 m.

(6) At present, the annual output of the station can be assessed at 90 million KWH of which 85 million are generated in the winter period from 1 December to 31 March. With the UPPER TAGLIAMENTO flow included, and assuming the same hydrologic conditions, production is expected to increase to 160 million KWH of which 105 million will be generated in the winter season. The load factor of the power station is 0.31. With the three units of 26,000 KVA installed at the power station (total 78,000 KVA) capable of passing up to 5.5 m^3/sec (making a total of 16.5 m^3/sec), the present winter production can be concentrated into less than 1500 hours.

A-06. PIAVE RIVER.

a. General Description (Basis: Reference 75)

(1) The PIAVE River ranks fifth among the Italian rivers. It is 220 km long and has a drainage area of 4100 km^2. Its important tributaries are the ANSIEI, BOITE, MAE, and CORDEVOLE (AGARDINO). The PIAVE is navigable for approximately 34 km upstream from CORTELLAZZO.

(2) The PIAVE River originates in the DOLOMITES at MONTE PERALBA (2683 m elevation). In the upper part, its drainage area is very narrow but enlarges when it enters the VALLEY OF BELLUNO. Numerous alluvions are found there. At QUERO, the valley contracts; during the glacier invasions a

morainal "amphitheater" was formed here. The MONTELLA alluvial cone of Pliocenic origin marks the end of the Alpine region. Beginning there, the PIAVE enters the VENETIAN PLAINS through which it flows as far as PONTE DI PIAVE. From there it follows a straight canal leading to the junction with the ADRIATIC SEA at CORTELLAZZO.

(3) At PEDEROBBA the river is 1000 m wide. At FALZE, northeast from MONTELLO, the width is 250 m; however, at the exit of NERVESA it is 600-880 m, and near CIMADOLMO is 4000 m.

(4) Beginning at CIMADÒLMO, the PIAVE is divided into numerous branches which form numerous so-called "grave," large gravel areas with layers of coarse sedimentary materials and sand, as well as brush-covered islands. The mouth of the PIAVE is marked by dunes built up by wave action.

(5) Due to the lack of forests and natural lakes in the upper part of the drainage area, the flow of the PIAVE is extremely variable. The discharge during the flood period amounts to 100 times the low water flow. The flood water also enlarges the bed of the river. This often results in a total displacement of the main bed and also causes sediment to accumulate along the river course.

(6) Precipitation over the drainage area averages 1500 mm per year. This figure is not directly reflected in the river flow because snow comprises most of the precipitation in the upper reaches and because of variation in the runoff coefficient. In this respect, the PIAVE regime is similar to the other Alpine rivers of VENEZIA. Low water occurs in the middle of winter followed by flood water in May or June; stages drop in August and September and often rise to flood stage in October or November depending upon the amount of rainfall.

(7) At BELLUNO the minimum discharge is 40 m^3/sec, high water flow is 300 m^3/sec. However, 2500 m^3/sec were carried during the catastrophic flood in September-October 1882. The mean yearly discharge is 120-130 m^3/sec. These figures are subject to adjustment due to the influence of recently constructed hydraulic structures. The weir at SOVERZENE now withdraws 40 m^3/sec into the LAGO S. CROCE and the LIVENZA River development. Irrigation of approximately 50,000 hectares is afforded mainly by the BRENTELLA and VITTORIO Canals. These withdraw 46 and 26 m^3/sec respectively for irrigation purposes.

b. Hydraulic Developments.
(Basis: References 2, 22, 23, 35, 37-46, 55, 76-82)

The principal hydraulic developments on the PIAVE River and its tributaries can be divided into the following major

groups, according to the utilization of flow for power production, flood protection or regulation, and irrigation or drainage:

(1) PIAVE-ANSIEI Development
(2) PIAVE-BOITE-VAJONT-SOVERZENE Development
(3) MIDDLE and LOWER PIAVE Development
(4) BOITE River Development
(5) CORDEVOLE River Development
(6) LIVENZA-PIAVE Development

c. PIAVE-ANSIEI Development. (Basis: References 28,39-42)

(1) General. This development was one of the first projects. It was built in 1926-31 and utilizes the flow of the upper PIAVE River and its tributary, the ANSIEI River. It consists of two dams, S. CATERINA Dam and COMELICO Dam and power plant located at PELOS. The dams are respectively designated as Serial Nos. R-9 and R-10 on Plate 1 and in Table 4 of this report.

(2) S. CATERINA Dam. (Serial No. R-9) (Basis: References 28, 39-41)

(a) S. CATERINA Dam is located on the ANSIEI River. It was constructed during the period 1930-31 and is a gravity-type concrete dam. Pertinent features are as follows:

Drainage area	205 km^2
Length of dam at the crest	185m
Height of the structure	53m
Crest elevation	833m above msl
Maximum stage elevation	830m above msl
Minimum stage elevation	806m above msl
Minimum storage capacity	6.7 million m^3
Area of the storage lake	50 hectares

(b) The flood water release is regulated by 2 spillways on the top of the dam, each consisting of 3 siphons. Each siphon is 3.20 m wide (see Ref. 41, Fig. 4). The siphon sills are at elevation 830.0 m, 830.1 m, and 830.2 m with corresponding heights of 2.0 m, 1.9 m, and 1.8 m. The capacity of the spillway is 300 m^3/sec. The bottom outlet conduit has its intake on the right bank. Its capacity is 100 m^3/sec. It is equipped with 2 gates, 3.5x4.0 m; one of these gates is at the upper pool entrance, the second is on the ANSIEI exit of the conduit. The gates are constructed so as to resist the pressure created by 35 m head above the sill. The operating mechanism is located 37 m above the sill opening. On the left bank of the upper pool at elevation 801.25 m, is the entrance into the power conduit. The intake is regulated by 2 valves located in the valve chamber. This conduit

is of 2.50 m diameter and joins the power conduit leading from the COMELICO Dam after crossing the PIAVE valley on a steel bridge of 37 m span. For a distance of 111 m at that place, the conduit crosses the PIAVE valley in 2 pipes each of 1.66 m diameter. The static pressure in this conduit is 35 m (see Ref. 41, Figs. 3b, 4 & 20).

(3) COMELICO Dam. (Serial No. R-10)
(Basis: References 28, 39-42)

(a) General. COMELICO Dam on the upper PIAVE River is a concrete arch dam. It was constructed during the period 1930-31. The dimensional data of this dam are as follows:

Drainage area	400 km^2
Length of the dam at crest	113 m
Height of the structure	66.50 m
Height above floor of valley	44.50 m
Crest elevation	832.50 m
Maximum stage elevation	831.50 m
Minimum stage elevation	806.50 m
Thickness of wall at crest	1.50 m
Thickness of wall at foundation level	8.65 m
Storage capacity	2.07 million m^3
Area of storage lake	13 hectares

(b) Dam Structure. The maximum length of the circular crest of the dam is 47.10 m corresponding to 136 degrees. The curvature of the arch changes with elevation (see Ref. 42, Figs. 7 & 9). The flood water outlets are constructed for 800 cm^2 capacity, which correspond to approximately 2 m^3/sec per km^2 of drainage area.

(c) Spillway. The spillways are arranged in 2 groups : the first group has 8 "chalice-shaped", elliptical openings 6x3 m at 6 m distance from each other. The elliptical overflow at 830 m elevation is 16 m long for each individual opening. The flow capacity of this first group of spillways is 390 m^3/sec at 1.5 m head. These spillway openings connect at the lower end with the bottom outlet conduit (see Ref. 42, Figs. 13 & 14). The second spillway is located nearer to the dam and has 4 openings. Three of them are identical with those of the first spillway and are at elevation 830.2 m. The fourth is of rectangular shape and serves as a middle outlet conduit for the dam at elevation 820 m. The 3 openings of the second group of spillways carry 160 m^3/sec at 1.3 m head. All of these spillway outlets are ventilated in order to avoid adverse pressures. The bottom outlet has its intake at elevation 795.50 m and is 12.50 m^2 in cross-sectional area.

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The portion in the upper pool is 51.40 m long. Flow is regulated by a 3.5x4 m gate from a central tower 37.90 m high (see Ref. 42, Fig. 15). The cross-section of the control tower shaft measures 3.88x3.50 m.

(d) Outlets. The tailwater part of the bottom outlet has a horseshoe-shaped cross-section, 6 m wide and 6 m high with 30 m^2 area and 258 m length. The flow capacity of the bottom outlet is 100 m^3/sec. The middle outlet conduit is combined with the second group of spillways, as already mentioned. At elevation 820 m, it is equipped with a 3.5x6 m gate. This outlet has 150 m^3/sec flow capacity. A summary of maximum outlet capacities follows:

First group of spillways	390 m^3/sec
Second group of spillways	160
Bottom outlet	100
Middle outlet	150
	800

(e) Pressure Conduit. The entrance to the pressure conduit is located on the left bank of the upper pool. The conduit is of circular cross-section 2.90 m in diameter, reinforced by a 0.25-0.30 m thick concrete lining for 518 m (see Ref. 20, Figs. 1, 2, 4 & 16). The valve chamber, located 58 m from the intake, has 2 regulating valves each 1.60 m diameter to regulate the flow into the river. After joining the power conduit from the ANSIEI-S. CATERINA DAM, the diameter of the conduit is 3.60 m. The junction of these 2 conduits is located at such an elevation as to create equal pressures in the sections leading from the COMELICO as well as from the S. CATERINA DAM. The maximum discharge from S. CATERINA DAM is 18 m^3/sec, from COMELICO DAM 16 m^3/sec, totaling 34 m^3/sec. The total length of the 3.9 m diameter conduit to the power plant at PELOS is 4,792.75 m.

(4) PELOS Power Plant. (Basis: References 41 & 42) The utilized flow in the power plant is 34 m^3/sec at the mean hydraulic head of 120 m. The power conduit bringing the flow from the COMELICO and S. CATERINA storage reservoirs ends in a surge chamber with piezometric shafts permitting oscillation up to 840 m elevation. Two penstocks of 2.30 m diameter carry the flow to 3 groups of turbo-alternators, each 21,000 KVA capacity. The turbines are located at elevation 683.5 m. Annual production of the plant is 140 million KWH.

d. PIAVE-BOITE-VAJONT Development.
(Basis: References 29, 35-39, 43-46, 76, 78, 82)

(1) General.

A-06 d (1)

(a) This development consists of the following major elements:

1. PIEVE DI CADORE DAM and Reservoir (Serial No. R-11)
2. VAJONT DAM (Proposed)
3. GALLINA DAM and Reservoir (Serial No. R-13)
4. SOVERZENE WEIR and Power Plant (Serial No. R-14)
5. VALLE DI CADORE DAM and Reservoir (Serial No. R-12)
6. PERAROLO Power Plant

(b) This vast hydraulic project was started shortly before the war as part of the electrification program of Italy for war purposes. However, the major part has been constructed since 1946 and partly placed in operation in 1949. Since then, the project is still under construction and further development. It comprises the development of the PIAVE River between PELOS power plant at elevation 683.5 m and the PIAVE-S. CROCE Development which utilizes the flow beginning at elevation 390.0 m.

(2) PIEVE DI CADORE Dam. (Serial No. R-11)
(Basis: References 29, 35, 37, 39, 43, 46, 80)

(a) General. The PIEVE DI CADORE Dam was constructed during the period 1947-50. After extensive studies and geologic investigations, the location of the dam was selected at PIAN DELLE ERE, below PIEVE DI CADORE. The dam site is located in dolomite limestone of the upper Triassic period. The cross-section is trapezoidal, with 55 m height in the middle, and 300 m wide base. At the right side of this valley the PIAVE River eroded a very narrow gorge of 55 m depth with considerable convexity toward the valley axis. The highly unsymmetric shape of this cross-section created a special problem in shaping the structure (see Ref. 44, Figs. 12, 13, 15, 16 & 17, or Figs. I-III on Plate 8b of this report). The dimensional data of this gravity arch dam are as follows:

Length of dam at crest	410 m
Maximum height of structure	112 m
Crest elevation	685.00 (msl)
Maximum stage elevation	683.5 (msl)
Minimum stage elevation	625.50 (msl)
Storage capacity	64.3 million m^3
Area of the storage lake	58 hectares

(b) Spillways. It is estimated that the flood flow may reach 1200 m^3/sec. For this flow the dam is equipped with a spillway of 700 m^3/sec capacity which may be closed by 2 gates each 9x6.9 m. The outlet gallery has a horseshoe shape 7 m wide and 140 m long lined with concrete. The gallery ends in an open concrete canal chute 180 m long and up to 23 percent gradient.

(c) Outlets. Besides the spillway, the dam is equipped with a bottom outlet at elevation 588.47 m and a middle outlet at elevation 613.50 m. (see Plate 8b of this report) At full head, these 2 outlets carry 500 m^3/sec.

(d) Power Conduit. The intake structure for the power conduit is at elevation 619.78. The power conduit consists of 2 concrete-lined circular galleries each 3.5 m in diameter. They end in 2 control chambers which are accessible from a platform at 636.00 m by means of a shaft. The regulation of the power flow is by a sluice gate and butterfly valves. Below the valve chambers, the conduits join a single pressure conduit 4.5 m in diameter. This conduit is 18.8 km long and ends at the junction with the power conduit from the proposed VAJONT Dam. It changes its diameter from 4.5 to 4.7 m and continues for a distance of 5.8 km until it reaches a second junction with a conduit already in operation leading from the VAL GALLINA Dam (Serial No. R-13).

(3) VAJONT Dam. (Basis: Reference 76 & 79) This dam is still in a proposed stage, although start of construction is planned for the very near future. It is located near LONGARONE on the VAJON River, a tributary of the PIAVE. The project provides for a concrete arch dam over 200 m high to form a reservoir of 58.2 million m^3 storage capacity. The pressure conduit from the PIEVE DI CADORE Dam of 4.5 m diameter, already in operation, will be joined by the pressure conduit from the proposed VAJONT storage reservoir.

(4) VAL GALLINA Dam. (Serial No. R-13)
(Basis: References 29, 35, 37, 39, 43, 45, & 78)

(a) Dam Structure. VAL GALLINA Dam is a "cupola"-type concrete dam with an unusual shape necessitated by the characteristics of the GALLINA River valley at the dam site (see Figs. 21, 24 & 25 of Ref. 45); particularly to be mentioned is the horizontal curvature of the dam and its very slim and curved form in the vertical cross-section. The dimensional data of the dam are as follows:

A-06 d (4) (a)

Length of dam at crest	240 m
Height of structure	92 m
Maximum stage elevation	677 m above msl
Minimum stage elevation	607 m above msl
Crest elevation	679 m above msl
Storage capacity of reservoir	5.9 million m^3
Area of storage lake	20 hectares

(b) Spillway and Outlets. The flood water is discharged over the spillway through 7 openings in the center of the dam crest. A bottom outlet serves for emptying of the dam in emergencies. In order to bring the power flow from the PIEVE DI CADORE storage reservoir (Serial No. R-11) and in the future from the proposed VAJONT reservoir, one branch of 3.5 m diameter crosses the GALLINA valley on a bridge and joins the pressure conduits of GALLINA Dam below the intake. There are two pressure conduits each of 5.0 m diameter and 2550 m length leading from GALLINA storage reservoir to the power plant at SOVERZENE.

(5) SOVERZENE Power Plant. (Reference 46)

Two pressure conduits of 5 m diameter each carry the power flow from the existing PIEVE DI CADORE and VAL GALLINA storage reservoirs and from the proposed VAJONT reservoir to feed the SOVERZENE power plant located at elevation 390.00 m. The special conduits lead first into a surge chamber with 4 piezometric shafts each 4.5 m in diameter and with expansion space permitting the accumulation of the flow up to elevation 705.15 m before entering the penstock. The penstock has 4 pipes of 2.60 m diameter and 135 m length built of pre-stressed reinforced concrete. The power flow is conducted to 4 groups of power generating units consisting of vertical Francis turbines of 55,000 KW capacity and an alternator of 60,000 KVA capacity generating 10,000 volts. The total installed capacity is 140,000 KVA and the estimated annual output is 650,000 KWH. The discharge conduit from the power plant is 6.4 m in diameter and 950 m long. This carries the tailwater directly into a canal (PIAVE-S. CROCE) leading to S. CROCE Lake to be further exploited for power generation.

(6) VALLE DI CADORE Dam (Serial No. R-12)
(Basis: References 35, 37, 39, 43, 45 & 76)

(a) General. This dam developed on the BOITE River, a tributary of the PIAVE, is also a "cupola" dam or, as it is sometimes referred to, a "double arched" dam. It was built during the period 1949-50. Its major dimensional data are:

A-06 d (6) (a)

Length of dam at crest	38 m
Height of structure	62 m
Crest of dam elevation	710.75 m above msl
Maximum stage elevation	710.50 m above msl
Normal stage elevation	706.50 m above msl
Storage capacity	5.6 million m^3
Area of storage lake	25 hectares

(b) Spillways and Outlets. Two spillways pass flood water: the first is located in the middle of the dam crest with a 16x4 m opening; the second is located on the left bank with a 8x13.5 m opening with a chute leading to the tailwater of the river. The bottom outlet is at elevation 654.5 m; the power conduit is 2.8 m in diameter and 4485 m long leading into the surge tank of the power plant at PERAROLO. This power conduit crosses the PIAVE valley on a bridge of 48 m span to reach the power plant located on the left bank of the PIAVE River.

(7) PERAROLO Power Plant. This plant is located on the left bank of the PIAVE River at its junction with the BOITE River. It was developed first as a provisional plant for partial utilization of flow from PIEVE DI CADORE Dam (Serial No. R-11) during its construction period up to 1948. Since then, it utilizes the power flow from VALLE DI CADORE Dam (Serial No. R-12). Its future role will be decided within the general framework of the MIDDLE PIAVE power development program. The plant is equipped with one turbo-alternator unit of 21,000 KVA.

e. MIDDLE AND LOWER PIAVE Development.
(Basis: References 2 & 66)

(1) General. The development of the MIDDLE and LOWER PIAVE consists predominantly of irrigation canals and pertinent structures combined with power generation. The two leading canals are the BRENTELLE DI PEDEROBBA and the DELLE VITTORIE.

(2) BRENTELLE DI PEDEROBBA Canal. At PONTE DI FENER, a movable weir across the PIEVE River dams the flow to a level permitting entry of water into the intake of an irrigation canal on the right bank. The weir is equipped with automatic segment gates permitting rapid discharge of flood-water. The intake structure is equipped with a settling plant for clearing the canal flow of undesirable solids. The flow capacity of the canal is 46 m^3/sec, of which 14 m^3/sec are returned to the PIAVE River through power plants at PEDEROBBA, RUGE DE GALLO, CASTELVIERO, and PONTE DI PRIULA. The total area irrigated by this canal is 44,000 hectares. The secondary canals fed from the main line are ASOLO MASER, BRENTELLA DI BOSCO, and BRENTELLA DI CAERANO. Localities subject to irrigation are: CROCETTA DEL

A-06 e (2)

MONTELLO, MONTEBELLUNA, MASER ASOLO, CASTELFRANCO, VENETO, RIESE, ALTIVOLE, VEDELAGO, TREVIGNANO, and VOLPAGO DEL MONTELLO.

(3) DELLE VITTORIE Canal. At NERVESA DELLE BATTAGLIA, the weir across the PIAVE River creates a pool provided with a sluice on the right bank carrying the flow into the irrigation canal. A settling basin in front of the canal entrance provides for removal of solid material from the flow. The flow capacity of this canal is 19 m^3/sec; part of it is restored and utilized for power generation at the power plant at CASTELLETO. The secondary canals are : DELLE PRIULLA, PIAVESELLA, and DI PONENTE. The area irrigated by this system is 26,000 hectares. The irrigated localities are : ARCADE, BREDA DI PIAVE, CARBONERA, ISTRANA, MASERADA, MELMA, MORGANO, NERVESA DELLA BATTAGLIA, PAESE, PONZANO VENETO, POVEGLIANO, QUINTO DI TREVISO, SPRESIANO, S. BIAGIO DI CALLALTA, TREVIGNANO, TREVISO, VILLORBA, and VOLPAGO DEL MONTELLO.

f. BOITE RIVER Development. (Basis: References 46&77)

Since 1948, the power plant at CAMPO DI SOTTO has been in operation as a first step in the hydroelectric power development of the upper part of the BOITE River. The entire development, which is still partly in planning and construction stages, includes the power plants at S. UBERTO, VODO and VENAS with 2 storage reservoirs at CAMPOCROCE (4.8 million m^3 near D'AMPEZZO) and at PODESTAGNO (38.9 million m^3 near POMPAGAGNON).

g. CORDEVOLE Development. (Basis: References 23 & 77)

(1) This development consists of 3 power plants utilizing the storage reservoir of LAGO DI ALLEGHE (Serial No. R-16). This reservoir was developed during the period 1938-42 by construction of a small dam across the CORDEVOLE River. Its storage capacity is 3.4 million m^3; the elevation is 968 m at maximum pool and 960 m at minimum. Following are the 3 power plants:

(a) CENCENIGHE: in operation since 1939, 30,000 KVA capacity, utilizing also the flow of the BIOIS and LIERA SPRINGS.

(b) AGORDO: in operation since 1940, 30,000 KVA capacity, also utilizing the flow of the CARPASSA.

(c) STANGA: in operation since 1943, 35,000 KVA capacity, utilizing the flow of the SARZANA, ROVA, BORDINA, MISSIAGA, CLUSA, VESLOVIA.

A-06 g

(2) Under construction are 2 dams near FEDAIA LAKE on the AVISIO River creating a storage reservoir of 16 million m^3. This storage will be redirected to be utilized for power at CENCENIGHE power plant.

h. LIVENZA-PIAVE Development.
(Basis: References 28, 38, 39, 43, 46 & 76)

The weir across the PIAVE River at SOVERZENE (Serial No. R-14) directs the flow into an open canal leading into S. CROCE LAKE (Serial No. R-6). The tailwater from SOVERZENE power plant, amounting to 84 m^3/sec is also directed into this canal to contribute to power generation in the LIVENZA River hydroelectric power development. This development consists of 6 major power plants and 2 storage reservoirs, the LAGO MORTO (Serial No. R-7) and the LAGO RESTELLO (Serial No. R-8). The storage capacity of S. CROCE Lake is 120 million m^3, LAGO DI MORTO 3 million m^3. The power plants in operation are as follows:

		Start of Operation	Capacity (KW)
(1)	FADALTO	1923	90,000
(2)	NOVE	1925	65,000
(3)	S. FLORIANO	1923	5,000
(4)	CASTELLETTO	1923	6,500
(5)	CANEVA	1927	36,000
(6)	LIVENZA	1930	7,000

A-07. BRENTA RIVER (Basis: Reference 3)

a. The BRENTA River originates in the CALDONAZZO Lakes and LEVICO, elevation 440.0 m near PERGINE. This also represents the dividing point between the ADIGE and BRENTA drainage areas. The total length of the BRENTA river is 174 km.

b. The river follows an east-west course in the VAL SUGANA for approximately 50 km to STRIGNO. The VAL SUGANA in this part was formed by the fault line of the dolomitic VICENTINE PRE-ALPS against the archaic schist-granite zone of CIMA D'ASTA. The valley shows considerable deposits of Mesozoic alluvions. It turns first towards the southeast and, after passing through a narrow gorge at PRIMOLANO, changes to the south after receiving its largest tributary, the CISMON. After a distance of 100 km, the BRENTA leaves the mountainous region and enters the plains of VENEZIA at BASSANO.

c. The main tributaries of the BRENTA above BASSANO are all on the left side; namely, the MASO, GRIGNO, and the CISMON. The latter is the most important, being 53 km long and having a 642 km^2 drainage area. The drainage area of the BRENTA River at this junction is 673 km^2. The CISMON is fed by the glaciers of the DELLE PALE group near S. MARTINO DI CASTROZZO and represents the major contribution to the BRENTA flow.

A-07

d. The total drainage area of the BRENTA River is 2310 km^2, of which 1567 km^2 is located in the Alpine part of the basin. The precipitation amounts to 1600-2000 mm per year. However, most occurs in spring and autumn and results in floods in those seasons. Winter is the main dry period in which the riverbed is usually completely dry. In summer, melting of glaciers provides the major source of flow.

e. Below BASSANO, the BRENTA is divided into numerous canals serving for irrigation and also for industrial use. Most of these canals were in existence since the Middle Ages and were built by the Venezian Republic. Most of this diverted flow is restored to the main river by canals such as the PILA, BRENTELLA-PIOVEGO, CONTARINA, and PIOVEGO DI VILLABOZZA. At PONTE VIGODARZERE, the BRENTA is joined by the MUSSONE DEI SASSI, the only major tributary in the lower reach of the river.

f. At LIMENA, the BRENTA River's low-water flow is transferred into the BRENTELLA CANAL, which joins the BACCHIGLIONE River at VOLTA BRUSEGANA. From LIMENA, the BRENTA proceeds southeast to STRA. There it is crossed by the navigable VENEZIA-PADOVA Canal. The part of the canal on the right side of the BRENTA (CANAL PIOVEGO), receives its water from the BACCHIGLIONE River. The left side part of the canal (NAVIGLIO BRENTA), follows the old BRENTA bed into the lagoon of VENICE. A movable weir on the BRENTA at STRA regulates the flow between the main river and the navigation canal.

g. From STRA the river follows a 30 km long straight artificial bed called "LA CUNETTA," which is of major importance. The large protective structures on both sides reach enormous proportions. This artificial bed of the BRENTA passes near PIOVE DI SACCO and through CODEVIGO and CONCHE with one outlet into the lagune (lagoon) near CA PASQUA. Here it is joined by the BACCHIGLIONE River. This final part of the BRENTA-BACCHIGLIONI River, called "TRONCO COMUNE," is joined from the right by a small tributary, the TRENTON River, which can be shut off by a segment gate. Also, the CUORI CANAL joins the BRENTA in two separate branches, one equipped with a navigation lock, the second with a segment gate. Three other canals joining the BRENTA SEA junction part are the GORZONE, CANAL DI VALLE, and BUSIOLA, all equipped with hydraulic structures serving primarily for navigation. The concentration of flow from different canals and tributaries in the artificial BRENTA River bed, results in high discharge. This necessitated unusually large and strong flood-protection structures along this waterway. This waterway serves as the border between VENEZIA and PADOVA Provinces.

A-08 BACCHIGLIONE RIVER. (Basis: Reference 3)

a. BACCHIGLIONE is the name of the river formed by confluence of several torrential streams such as the TIMONCHIO, LEOGRA, IGNA, and ROLA, at VILLAVERLA, a short distance from VICENZA. However, the main contribution to the flow comes from the ASTICO River with its numerous tributaries which joins the BACCHIGLIONE under the name of TESINA River at DEBBA.

b. The Alpine part of the BACCHIGLIONE drainage area is of Triassic and Cretaceous origin with predominance of dolomitic limestone, stratified and gnawed, followed in depth by crystaline and dolomitic limestone. This may explain why part of the flow disappears underground.

c. The BISSATTO Canal, which usually takes the total low flow of the BACCHIGLIONE branches off to the right at LONGARE. This canal later takes the name of ESTE-MONSELICE and restores its flow back to the BACCHIGLIONE through the CANALE DI BATTAGLIA at VOLTA BRUSEGANA after receiving several small tributaries.

d. At BASSANELLO near PADOVA, the BACCHIGLIONE divides into three parts. One is the CANALE DI BATTAGLIA, the second is the CANALE SCARICATORE and the third is the TRONCO DE MAESTRO. The latter feeds the canals of the city of PADOVA and continues as PIEVEGO CANAL to the BRENTA River at STRA, and as the RONCAITTE runs into the CANALE SCARICATORE BATTAGLIA Canal and RONCAITTE carry their flow into the CANALE DI PONTELUONGO; which is joined by several branches to the ESTE-MONSELICO Canal. The PONTELUONGO Canal is the artificial bed for the BACCHIGLIONE River which joins the artificial bed of the BRENTA River at CA PASQUA (CA PASCA).

e. The hydrologic regime of the BACCHIGLIONE River is extremely variable. At BRUSEGANA flow reached 840 m^3/sec at HHW and fell to 30 m^3/sec at LLW. (Different figures are given by Prof. Almaggia). Floods usually appear in October-November and March-May. The spring floods are usually higher than the fall floods.

f. The complicated canal system originating in the very early history of Northern Italy is particularly famous for its many structures built during the period of high prosperity of the medieval Republic of VENEZIA. Those canals and hydraulic structures considerably influence the hydrologic regime of the BACCHIGLIONE River.

A-09 ADIGE RIVER.

a. General Description. (Basis: Reference 81)

(1) The ADIGE is second only to the PO River in length. Its total length reaches 404 km. It originates at the foot of PIAN DEI MORTI in the high Alpine region north of the village of RESIA, in the ALTO ADIGE Province of VENEZIA at 1586 m elevation. Sometimes the origin of the ADIGE is considered to be the lakes of RESIA, highest of which is at 1475 m, the middle (LAGO DI MEZZA) is at elevation 1445 m, above sea level. These two upper lakes have been dammed by S. VALENTINO DAM (Serial No. R-22) since 1951.

(2) The ADIGE enters VAL VENOSTA which has numerous large alluvial cones resulting from lateral currents and side streams which divert the ADIGE flow from one side of the valley to the other.

(3) At MERANO, the ADIGE is joined by the PASSIRIO River at elevation 293 m. The first major tributary is the ISARCO (EISACK in German) which joins at BOLZANO. The ISARCO originates on the Italian-Austrian boundary east of BRENNER PASS at 2000 m elevation above msl. It is joined by the RIENZA River which has its source at LANDRO, near DOBBIACO, in PUSTER VALLEY (near the DRAVA River source), another Italo-Austrian boundary point. The catchment area of the RIENZA at BRESSANONE is 2077 km^2, while the ISARCO, at this point of confluence, drains only 435 km^2. The ISARCO flow is twice as large as that of the ADIGE River and in all respects has the characteristics of a major stream instead of those of a tributary. Among other tributaries of the ADIGE River, the NOCE has 1396 km^2 and the AVISIO 956 km^2 of drainage area.

(4) Below TRENTO, the ADIGE River's violent currents attack the valley walls, and the river-bed in some places has been eroded to solid rock; however, after its exit from the Alps, the bed is covered with layers of recent sediments which stretch up to VERONA. This seems to indicate that this valley is of recent Pliocenic origin which was overrun by the moraines of RIVOLI.

(5) The contributing drainage area of the ADIGE River below TRENTO is considerably constricted and very few tributaries in this reach are worth mentioning as flow contributing factors. The BRENTA and SARCA Rivers belong to separate systems despite the fact that the BRENTA joins the ADRIATIC SEA near the mouth of the ADIGE River. The short parallel course of the SARCA River also is near that of the ADIGE.

A-09 a

(6) At the confluence with the TASSO River, the ADIGE River enters the VERONESE DEPRESSION. Between the junctions of the ISARCO and TASSO, the total drop is 148 m in 130 km corresponding to a mean gradient of 1.14 m per km. In the plains below VERONA the ADIGE River does not follow the general decline of the terrain. It joins neither the PO nor the BADIA POLESINE and flows independently towards the ADRIATIC SEA which it joins at FOSSONE.

(7) After the river leaves the ALPS, the height of the alluvial terraces above the terrain becomes greater while the general gradient of the stream continues to descend towards S. GIOVANNI LUPATOTO. From there the bed is elevated by its own alluvions above the surrounding terrain. These alluvions reach a maximum at LEGNAGO, BADIA, and BOARA. They decline from there on until they disappear at approximately 30 km distance from the sea. There again the river level conforms to the level of the valley. In the depression part of the river, both banks are lined by very strong flood dikes which accompany the river up to the sea. These structures aggravate the rise of the bed above the countryside and also create difficulties where the tributaries join the main stem of the ADIGE. Auxiliary channels are thus created near the stream junctions. Consequently, the drainage area of the ADIGE is considerably reduced, by the action of man-made protective structures than a result of natural conditions. It is estimated that 176 km of the ADIGE PLAINS have a mean width of 21.6 km which amounts to an area of 3810 km^2. Consequently, considering the entire drainage area of the ADIGE of 14,700 km^2, 75 percent of it belongs to the Alps and only 25 percent to the Plains. Although only 57 percent of the ADIGE course passes through the Alpine region, the slope of the river in the plains is only 0.5 m per km. The ratio between the total length of the ADIGE River (404 km) and the shortest distance between its source and mouth (235 km), amounts to 1.72. The mean slope of the river as a whole is 3.9 m per km.

(8) The ADIGE can be classified as an Alpine River considering its hydrologic and thermic conditions. Alpine streams are characterized by relatively greater influence of snow and glaciers over rainfall in determining the discharge. A great deal of solid material is carried by its flow at the Alpine periphery as well as in the plains. In January, at low discharges (100 m^3/sec.), ice drifts are formed which are carried as far as BADIA POLESINE. The ADIGE has 185 glaciers of 277.5 km^2 total area; 155 of them totaling 223.6 km^2 are in the ALTO ADIGE region, (formerly the Austrian Province of Tyrol).

(9) Melting of glaciers does not influence the flow until July and August; however, the flow from melting snow

begins in March. The ADIGE River, similar to other rivers of the VENETIAN PLAINS, is characterized by its great variation of discharges. It may reach the enormous proportion of 3500-4000 m^3/sec. As a rule the autumn floods are minor compared with those in the spring. Of 146 inundations observed in the ADIGE PLAINS, only 40 appeared in the October-November period; however, the most extensive flood observed to date was in September, 1882. This flood was due to unusual combinations of humid air accumulation from the ADRIATIC SEA and barometric conditions over the ALPS which resulted in high intensity of rain over the whole ADIGE drainage area.

(10) The lower part of the ADIGE is well protected on both sides by large protective structures and dikes, numerous pumping plants, draining siphons, diversion canals, etc. Some of these are of historical significance reaching back to the Middle Ages. In places these structures are designed for melioration purposes. The inland navigation on the lower ADIGE is of little significance.

b. Hydraulic Developments.

(1) The major hydraulic installations controlling the ADIGE flow, are predominently hydroelectric power developments, combined in some cases with flood protection structures, and only in minor cases with irrigation features. No navigation structures are involved. Utilization of the flow for power development is usually by means of long canals, tunnels, open channels, or pressure conduits, reaching in some instances to lengths of 50 km. Many of the power plants constructed in the period 1930-1940 are underground installations.

(2) With regard to possible flow utilization, the ADIGE River basin can be divided into the following major regions:

(a) UPPER ADIGE River above VERONA
(b) ISARCO River
(c) NOCE River
(d) AVISIO River
(e) LOWER ADIGE River below VERONA

c. UPPER ADIGE River, above VERONA.

(1) General. The hydroelectric developments located in the area of the ADIGE River above VERONA (km 141) including its tributaries exclusive of the ISARCO, NOCE, and AVISIO Rivers are described in subsequent paragraphs and listed in the following tabulation:

A-09 c (1)

(a) LAGO DI RESIA
(b) CASTELBELLO
(c) PLIMA River
(d) VERNAGO (SENALES River)
(e) PASSIRIO River
(f) MERANO
(g) LAGO DELLE PIAZZE
(h) MORI
(i) AVIANO River
(j) MEDIO ADIGE
(k) SORIO

(2) LAGO DI RESIA Development.
(Basis: References 47, 51, 52 & 78)

(a) S. VALENTINO Dam (Serial No. R-22)

1. General. This dam utilizes the two existing natural lakes, LAGO DI RESIA and LAGO DI MEZZO, uniting them into one reservoir of 650 hectares surface area and 6.5 km length. The main dimensional data of the dam and reservoir are as follows:

Drainage area (322 re Ref.53)	310 km^2
Length of dam at crest	447 m
Height of dam above valley	31.5 m
Maximum stage elevation	1495 m above msl
Minimum stage elevation	1464 m above msl
Mean utilized head	580 m
Storage capacity	110 million m^3 (120 re Ref. 47)
Area of the reservoir	650 hectares

2. Hydrologic Conditions. Of the total 310 km^2 included in the drainage area, 23 km^2 consist of glaciers. Hydrologic investigations indicated 0.0211 m^3/sec per km^2 as the mean runoff and 5.8 m^3/sec as the mean utilized flow at the damsite.

3. Dam Structure. The dam is an earth gravity type. It has an impermeable core consisting of a mixture of earth and bentonite (a special material mined near NAPLES). The dam is anchored into the terrain by a wall of reinforced concrete, averaging 22 m high, built on solid rock, with its lowest point at 1450.50 m elevation. Inside this wall is an inspection gallery. The dam is 7.0 m wide at the crest, 186 m wide at the foot. The crest of the dam is at 1500.80 m elevation, 31.5 m above the floor of the valley. The crest is 3.0 m above the high water mark and 4.0 m above the normal

stage of the reservoir, which is at 1496.80 m elevation. A drainage system under the tailwater side of the dam with a drain collector, provides an outlet for seepage. (Sketches of the structure are shown on Plate 8c of this report.)

4. Scour Tunnels. Because of sudden floodwater possibilities prevailing in all Alpine rivers, the outlet installations are abundantly dimensioned. The first "scour tunnel", with an intake at 1472.0 m elevation, has a flow capacity of 130 m^3/sec; the second, at elevation 1467.68 m, has 300 m^3/sec capacity.

5. Spillways. The spillways were designed to carry 865 m^3/sec. However, all outlets combined are able to discharge 1761 m^3/sec when the head over the spillway is 1.65 m. This is sufficient to handle a catastrophic flood of 5.7 m^3/sec per km^2 of drainage area. The 3 spillways are of Creager type with circular crests of 22 m diameter. The total developed length of the overflow crest is 188.50 m. The spillways have a "chalice-like" shape and are entirely surrounded by the water of the reservoir pool (see Fig. III of Plate 8c of this report). The coefficient of discharge for these 3 circular spillways operating as a unit is 0.49. Individually, the spillways have discharge coefficients of 0.51. These values were checked on models at the Milano Technical University.

6. Power Tunnel. Water is conveyed to the power house by a tunnel consisting of a pressure conduit located within the rock on the right bank. The conduit crosses the ADIGE valley 1700 m from the dam on a bridge of 2x17.0 m span built of concrete tubular beams. The conduit has 3.0 m diameter, 0.1 percent gradient, and is 12 km long. Discharge capacity is 65 m^3/sec. Approximately 2800 m of the conduit is lined with reinforced concrete; inside surface of the remaining portion is treated with cement. The pressure conduit is equipped with auxiliary intakes on the PUNI and SALDURA (5 and 10 m^3/sec flow capacity, respectively), tributaries of the ADIGE. The conduit ends in a surge shaft with 2 expansion chambers at 1450.30 m and 1490.0 m elevation. A valve chamber at elevation 1439.66 m provides for regulation of the power flow from the pressure conduit into the penstock of the power station.

(b) GLORENZA Power Plant.

1. Surge Tank. The surge chamber of this power plant consists of a horizontal expansion chamber at the conduit level and an inclined shaft of large diameter leading to a second upper horizontal cylindrical chamber. An inclined shaft of smaller diameter leads up to the rock surface

from the upper chamber. A valve chamber is located downstream from the surge chamber at the upstream end of the penstock.

2. Penstock. The penstock consists of a welded pipe, laid within a tunnel. Its diameter varies from 2.5 to 2.1 m. The lower portion is reinforced with "shrunk-on" steel bands.

3. Machinery. Two sets of turbo-alternators each 58,000 KVA capacity are provided. Each set consists of an alternator driven by two Pelton wheels. The total capacity of the plant is 116,000 KVA, and the annual power output is 273 million KWH. The whole power plant is underground.

4. Tailrace. The tailrace of the GLORENZA power plant leads into the ADIGE River. As the ADIGE valley is fairly wide here, a reservoir of 270,000 m^3 capacity has been built to provide storage for operation of the CASTELBELLO plant located downstream from this location.

(3) CASTELBELLO Development.

(a) Weir. Eight kilometers below the junction of the tailrace of the GLORENZA power plant with the ADIGE River, there is a weir across the river equipped with sluice gates to control the flow diverted to the power plant at CASTELBELLO. The weir is 34 m long with 2 openings each 12 m wide and 1 opening 6 m wide, equipped with sluice gates 4.5 m high. The diverted flow passes into a two-chambered sand settling system of 82.5 m total length. It then enters a circular pressure conduit of 4 m diameter and 17.4 m length. A storage basin of 22,000 m^3 capacity is located close to the intake. Because the configuration of the valley limits storage, an additional 22,000 m^3 is provided in a chamber excavated along the line of the tunnel. The flow released from the 270,000 m^3 reservoir below GLORENZA Power Plant (described in preceding paragraph) takes about 1 hour to reach the intake of the CASTELBELLO power plant conduit.

(b) Penstock. The pressure tunnel ends in a complicated surge chamber structure with an expansion chamber of 10,000 m^3 capacity. The penstock is 3.25 m in diameter, 516 m in length, and has a 1.85 percent slope. The draft tube of the turbines leads into a 215 m long discharge conduit which ends in an open tailrace canal 402 m long which joins the ADIGE at 1568 m elevation.

(c) Machinery. The main power station is 60x18 m in plan dimensions and is fully underground. It has 3

vertical Francis turbo-alternators of 32,000 KVA installed capacity. The transformers are above ground. The drainage area at CASTELBELLO is 1075 km^2. The gross hydraulic head is 294 m, utilized head is 279 m. The utilized flow is 30.0 m^3/sec; the mean annual flow is 18.2 m^3/sec. Installed power capacity is 96,000 KVA and annual output is 400 million KWH.

(4) PLIMA River Development.
(Basis: References 47 & 55)

(a) GIOVARETTO Dam. (Serial No. R-25)
This dam on PLIMA River has been under construction since 1951 and will form part of the power development known as "IMPIANTO PLIMA." The dam is constructed as a concrete wall reinforced by pillars. Pertinent dam data (according to Ref. 55) are as follows:

Storage capacity	15 million m^3
Maximum stage elevation	1850.00 m above msl
Height of the dam	100 m

(b) PLIMA Dam and Power Plant.
(Serial No. R-24)
Pertinent data concerning this project (according to Reference 47) are as follows:

Catchment area	1075.0 km^2
Storage reservoir	0.5 million m^3
Maximum stage elevation	1560.00 m above msl
Elevation of the plant	868.00 m above msl
Hydraulic head	690.00 m
Installed power capacity	52,600 KVA

(5) VERNAGO (SENALES River) Development.
(Serial No. R-23) (Basis: Reference 54)

(a) Purpose. This project is located on the SENALES River, approximately 15 km from its junction with the ADIGE. The dam has been under construction since 1950. The storage reservoir of 20 million m^3 provides annual storage for the smaller power plants of the cities of MERANO and BOLZANO. These power plants, known as "IMPIANTO TEL" and "IMPIANTO MARLENGO" have been constantly expanded since 1926.

(b) Dam Structure. The VERNAGO DAM (Serial No. R-23) was constructed as an earth gravity dam with a core of impermeable material, mostly clay. As packing material, a bentamite mixture is used (a special material mined in the south of Italy). The crest of the dam will be 43 m above the river bed.

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The proposed annual power output gained by the construction of this dam is 73.5 million KWH. The data of the dam are as follows:

Storage capacity	25 million m^3
Area of reservoir	140 hectares
Maximum stage elevation	1674.00 m above msl
Minimum stage elevation	1644.00 m above msl
Height of the dam	40 m
Length of dam at crest	300 m

(6) PASSIRIO River Development. (Basis: Reference 4)

This project has been planned since 1926 but its present status is not known. The capacity of the reservoir is 2.5 million m^3, the height of the dam 30 m. The dam is intended to provide floodwater protection of the city of MERANO, and also to prevent movement of sediment carried by the PASSIRIO River into the ADIGE River.

(7) MERANO Development. (Basis: Reference 82)

(a) TEL Power Plant. This project was developed in 1925-1926 by extension of the old NATURNO-TEL, the hydroelectric power development utilizing the flow of the SENALES River. The power plant is equipped with a movable sluice weir with two openings each 7.5 m wide plus a scouring outlet. The hydraulic data of the power plant are:

Drainage area	1663 km^2
Maximum stage elevation	505.60 m above msl
Hydraulic head	71 m

A power conduit leading to the surge chamber has 35 m^3/sec flow capacity. The penstock supplies two Francis spiral turbines each 7,600 HP connected with two alternating current generators each of 14,000 KVA capacity. The tailwater elevation is 430 m above msl.

(b) MARLENGO Power Plant. The tailwater of the TEL power plant is redirected into a reinforced concrete conduit 3.5 km long leading into the surge tank of the MARLENGO plant. The tailwater of the MARLENGO plant joins the ADIGE River at elevation 291.50 m above msl. The utilized hydraulic head in this power plant is 130 m. The installed power capacity of the power plant is 45,400 KVA. The power generating equipment consists of four units of 10,000 HP spiral Francis turbines and two direct current generators each 3,500 KW capacity.

(8) LAGO DELLE PIAZZE Development.
(Serial No. R-34) (Basis: Reference 55)

This development utilizes the water storage of LAGO DELLE PIAZZE Lake located on the PINE River, a tributary of the FERSINA, which joins the ADIGE at TRENTO. By building a rock fill gravity dam, stage elevation of the lake was elevated to provide a storage of 6.5 million m^3. The dam was constructed in 1926. The storage of the DELLE PIAZZE Dam is transferred, through a covered conduit, into AVISIO River to be utilized for power generation in the power plant at POZZOLAGO. The data of the dam are as follows:

Maximum elevation of lake	1027 m above msl
Minimum stage elevation	1022 m above msl
Storage capacity	6.5 million m^3
Area of the lake	37 hectares
Annual power output	45 million KWH

(9) MORI Development. (Serial No. R-35)
(Basis: Reference 62)

(a) General. This development was constructed in the period between 1928-1932 and provides electric power for production of aluminum. Pertinent data are:

Drainage area	10,410 km^2
Utilized hydraulic head	10.60 m
Installed power capacity	17,200 KVA

(b) Dam and Canal. The weir across the ADIGE River results in an upper pool elevation of 164.75 m above msl. (See Fig. 1 of Ref. 62) From the upper pool, the flow is redirected through a side opening (11.75 m wide and 3 m high, with a sill elevation of 171.75 m) into an open canal 2450 m long. The canal intake opening is equipped with an automatic gate hinged on the horizontal axis fixed to the sill of the opening (See Fig. 7 of Ref. 62). Tailwater from the power plant enters the ADIGE at elevation 152.0 m. The canal has the following hydraulic characteristics:

Cross section area	(A)	90 m^2
Velocity of the flow	(V)	2.70 m/sec
Friction coefficient	(f)	0.16
Hydraulic radius	(R)	3.08 m
Gradient	(I)	0.024%
Hydraulic coefficient	(C)	29.20 m
Discharge	(Q)	195 m^3/sec

(10) AVIANO River Development
(Basis: Reference 63)

(a) PRA DA STUA DAM. (Serial No. R-36)

1. This dam and reservoir was placed in operation in 1949, utilizing the flow of pre-Alpine streams, particularly of the AVIANO River, covering a catchment area of 37.84 km^2. The mean annual discharge on these streams amount to 60 liters/sec per km^2, corresponding to 0.6 m^3/sec mean annual discharge. Flow is regulated by the PRA DA STUA Reservoir, capacity 1.5 million m^3. It may be filled twice a year, in winter and in summer. A complicated system of auxiliary small dams and structures located at high elevations catches the runoff and carries it to the AVIANO River and thence to the PRA DA STUA Reservoir.

2. The dam is a gravity arch type. The foundation is of cretaceous limestone. The height of the dam from the foundation rock to the crest is 49.0 m. The data are as follows:

Capacity of reservoir	1.5 million m^3
Maximum stage elevation	1041.5 m above msl
Crest elevation of dam	1043.00 m above msl
Mean terrain elevation	1008.5 m above msl

(b) AVIO POWER PLANT. The utilized hydraulic head of the power plant is 843.05 m which required unusually strong penstock pipes as the hydrostatic pressure reaches up to over one hundred atmospheres. The diameter of the penstock is 0.47 m; the length is 1930 m. The penstock is anchored at 20 places and is supported by 300 pilasters. Two groups of Pelton turbines combined with 3-phase alternators each have a capacity of 3100 to 3770 KVA.

(11) MEDIO ADIGE Development.
(Basis: References 57 & 64)

(a) General. This development consists of two hydraulic developments: ALA-BUSSOLENGO Weir, Conduit, and Power Plant, and the BUSSOLENGO-CHIEVO Conduit and Power Plant.

(b) ALA-BUSSOLENGO WEIR. (Serial No. R-37)

1. This development was constructed during the period from 1939 to 1944 and is based on a discharge capacity of 135 m^3/sec. A movable weir across the ADIGE River at ALA-BUSSOLENGO controls the whole development. The weir has four openings each 25 m wide, equipped with 4.5 m high gates

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raising the stage to between 133.00 and 137.5 m above msl. Stored water is directed into a settling basin prior to entering the conduit. The entry into the settling basin is through sixteen openings each 3.5 m wide. The settling process is performed in six basins each 90 x 7.5 m. The plant at GASALKANT on the CIRCIK River in CENTRAL ASIA, USSR., was used as a model for this sedimentation plant.

2. From this settling basin, the flow is conducted through an open 39 km long canal, of trapezoidal cross-section, 9.30 m wide at the bottom, 21.0 m wide at normal level, and 6.0 m deep. The canal is designed for 145 m^3/sec flow capacity. Of this, 25 m^3/sec are used for irrigation purposes in the summer period between 15 April and 30 September. The utilized flow for power purposes consequently varies between 110 to 135 m^3/sec. In the winter season, the flow amounts to 90 m^3/sec. The irrigation area of 240 km^2 is located between LAKE GARDA and VERONA.

3. The flow is conducted from the open canal into a surge basin and thence by three reinforced concrete circular conduits of 4.0 m inside diameter and 5.6 m outside diameter, into the turbine units. The basin is provided with a spillway equipped with two automatic segment gates each 10 x 2.75 m, an emergency outlet 2.5 x 3.0 m and two scouring outlets 2.50 x 1.50 m and 2.50 x 1.0 m. The three turbines have vertical axes. They each have 45-48 m^3/sec flow and 16,500 KW power capacity. The total utilized head at the ALA-BUSSOLENGO part of the development is 39.5 m. The total power capacity is 49,500 KW; annual production is 280 million KWH. The tailwater elevation is 89.3 m above msl.

(c) BUSSOLENGO-CHIEVO Power Plant.

1. The tailwater of BUSSOLENGO power plant is redirected into a 7.5 km long canal, leading to the power plant located in CHIEVO near VERONA. The surge chamber is at elevation 88.85 m above msl. This plant has 3 Francis turbines, each with a discharge capacity of 45-48 m^3/sec and each generating 10,500 KW with a 24.75 m head.

2. The canal has the same dimensions as the ALA-BUSSOLENGO canal with 90 m^2 cross-sectionial area. Tailwater leaves the plant at elevation 64.0 m above msl. The combined lengths of intake canals on both developments is 46.5 km. The canals were constructed in rugged terrain, requiring a great deal of structural work. Approximately 8.5 km are contained in tunnels. At the open part of the canal are deep cuts and heavy bank reinforcements. Sluice gates are located at

approximately every 12 km to facilitate emptying of the canal into the river. Several valleys are crossed by aqueducts; the longest is 210 m long and has a 25 m maximum height and consists of five spans of 30 m concrete arches. Fifty-two road bridges cross the canal. The BUSSOLENGO plant is an important distribution center for twelve high-powered 135 KV transmission lines serving a great part of north Italy.

(12) SORIO Development. (Basis: Reference 23)

This hydroelectric development was constructed in the period from 1936 to 1938 near VERONA. The utilized flow amounts to 105 m^3/sec; the hydraulic head is 12 m. The power plant intake canal is 525 m long and has a 75 km^2 cross-section area. It serves two Kaplan turbines of 12,000 KW capacity. Maximum annual output is 50 million KWH. The power plant is constructed on caissons.

d. ISARCO River.

(1) General. The hydroelectric developments located in the ISARCO River basin are described in subsequent paragraphs and listed in the following tabulation:

(a) BRESSANONE
(b) PONTE DI GARDENA
(c) PREMESSA (GARDENA River)
(d) CARDANO
(e) TALVERA River

(2) BRESSANONE Development.
(Basis: References 47 & 48)

(a) General. This hydroelectric power development was built in the period 1940-1941 by the Societa Elettrica Alto Adige for purpose of production of power to be used on the government railroad from BRENNER to BOLZANO. The power plant is located at BRESSANONE near the junction of the ISARCO and RIENZA Rivers and utilizes the flow of both rivers. The general hydraulic characteristics of the development are as follows:

Discharge area	2620 km^2
FORTEZZA storage reservoir	3.21 million m^3
RIO DI PUSTERIA storage reservoir	2 million m^3
Utilized flow	80 m^3/sec
Utilized hydraulic head	164(162) m
Maximum power capacity	100,000 KW
Installed power capacity	143,500(142,500) KVA
Annual power output	600 million KWH

(b) FORTEZZA Dam. (Serial No. R-19)

1. Dam Structure. The dam is a concrete arch type, formed of horizontal circular rings, the radii of which range from 13.5 m at the foot to 31.275 m at the crest of the dam. The crest is 58 m above the floor of the valley and 63.50 m above the bottom of the foundation. The maximum stage elevation is 722.00 m above msl, which is also the elevation of the relief outlet. Minimum stage is 703.0 m above msl. The top of the dam is at 724.00 m and the length of the dam at the crest is 57.0 m. The reservoir pool has an area of 18 hectares.

2. Outlets. A relief outlet on the right side above the dam with crest elevation 722.00 m, and 380 m^3/sec flow capacity at 1.0 m head, provides for relief of floodwater. This emergency outlet is in the form of a very steep circular conduit 6.20 m in diameter. It joins an 8.0 m diameter outlet gallery carrying the flow into the ISARCO River. Flow over the crest of the dam is also anticipated in event of high flood conditions.

(c) RIO DI PUSTERIA DAM. (Serial No. R-18)

This is a gravity dam equipped with automatic gates, hinged to a horizontal axis on the crest of the dam. The maximum height of the crest is 22 m above the floor of the valley of the RIENZA River and 27 m above the bottom of the foundation. The maximum stage elevation is 723 .0 m, the minimum 711.0 m. The area of the reservoir is 28 hectares. Two openings on the top of the dam are 15 m wide and 4.0 m high, equipped with automatic hinged gates. Three bottom outlets of the dam have square cross-sections of 4.50 m provided with gates operated by mechanisms inside the dam. Stop-log emergency closures placed in front of the gates on the upstream side may be used for closure of the outlets for repairs.

(d) BRESSANONE Power Plant.

1. The circular concrete conduit from the FORTEZZA Reservoir has a 2.65 m diameter and is 1605 m long. The RIO DI PUSTERIA Reservoir conduit is also of circular cross-section, 4.60 m diameter, and 3282 m long. These two conduits join in a chamber in which are located the regulating and control gates. From there, a conduit of 5.20 m diameter and 5945 m long leads towards the surge chamber. All these conduits are under pressure which varies from 12.70 m at FORTEZZA Dam to 30.70 m at the entrance to the surge chamber. The surge chamber has a capacity of 19,000 m^3. A reinforced concrete circular conduit 5.80-4.70 m in diameter and 358 m long, transfers the flow to

the valve chamber regulating the flow to the turbines. The penstock consists of 4 steel pipes carrying the flow to 5 turbines, 3 of 35,000 KVA each and 2 of 18,650 KVA each power capacity.

2. It is to be noted that the entire power plant development was built underground for protection against bombing. It was built during the war with the intention of being used for wartime operations. Because of the underground location of the power plant, the draft conduit required special structural features.

(3) PONTE DI GARDENA Development.
(Basis: Reference 47)

(a) FUNES Weir. (Serial No. R-20) This weir is located at the junction of the FUNES and ISARCO Rivers. The movable weir (see Fig. 8 & 9 of Ref. 47) has 4 openings: 3 at 15.00 m wide and 1 at 5.0 m wide, all equipped with gates 4.0 m high. The lifting gates have 1.0 m high automatic flush gates with hinged horizontal axis. The gates are hand and power operated. On the right side above the weir are located 3 groins which serve for keeping coarse rubble and other material from entering the channel. An automatic scouring gate provides for clearing of sediment accumulated above the weir. The dimensions of the scour gate are 6.0 m wide and 2.8 m high. A summary of data follows:

Drainage area	3045 km^2
Utilized hydraulic head	61.50 m
Utilized flow capacity	80 m^3/sec

(b) PONTE ALL' ISARCO Power Plant. At the entrance into the power plant channel is located a Du Four sedimentation plant for clearing sand and other floating material from the flow into the plant. The sedimentation chamber is 7 m wide and 145 m long, divided at the end in 2 chambers. The whole intake structure is 355 m long. The power plant conduit is 7,540 m long and has an average 0.001 percent gradient. Its cross-section is semi-circular with a 2.90 m radius; however, in some places, the cross-section is entirely circular. The conduit ends in a gallery of 82 m^2 cross-sectional area and 200 m length leading to a surge chamber. The stage at this chamber is 524.50 m above msl. The penstock of 6.0 m diameter and 53.0 m head is excavated into rock and is of reinforced concrete. The penstock branches into two turbine intake pipes of 5.40 m and 4.40 m diameter. The installed power capacity of the power plant is 75,000 KVA.

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(4) PREMESSA (GARDENA River) Development.

The scanty available data regarding the PREMESSA power plant of the GARDENA River Development are as follows:

Drainage area	161 km^2
Utilized hydraulic head	321 m
Installed power capacity	11,200 KVA

(5) CARDANO Development.
(Basis: References 49 & 50)

(a) General. This development known as "L'IMPIANTO IDROELETTRICO DELL'ISARCO," is located between PONTE ALL'ISARCO (Serial No. R-21) and CARDANO on the ISARCO River. These places are 28.0 and 11.0 km respectively above the junction with the ADIGE River at ADIGE Km 236.11. This hydroelectric development at CARDANO, named "CARLO CICOGNA" near BOLZANO, was built during the period between 1926-1931. Up to the war, it was the largest hydroelectric power installation in Italy and was counted among the largest plants of Europe. Its installed power capacity is 271,000 HP, and its annual production is more than 500 millions KWH.

(b) Hydrologic Conditions. The plant utilizes the favorable flow conditions of the ISARCO River. It utilizes 80-100 m^3/sec (90 m^3/sec mean). The terrain elevation drops from 459.00 m above msl at the junction of the GARDENA valley on the ISARCO River above the weir at PONTE ALL'ISARCO (Serial No. R-21) to 276.0 m in EGA stream valley below the dam at the junction with the ISARCO River at CARDANO. The total drop in elevation amounts to 183.0 m.

(c) Intake Structures at PONTE ALL'ISARCO. (Serial No. R-21)

1. Weir. The movable weir at PONTE ALL'ISARCO across the ISARCO River has three openings of 15.0 m clear width and a sluice opening 4.0 m wide by 4.5 m high. The three openings are equipped with lifting gates 5.0 m high. The normal upper water stage is 462.00 m above msl, which is also the normal stage of the storage pond. The weir is electrically operated and operates efficiently and fast.

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2. Sedimentation Plant. On the right upper side of the weir, between the ISARCO River-flow and the storage pond, there is located a very elaborate sedimentation plant utilizing the Du Four system to remove sediment from the flow to the power units. (See Figs. 10, 17, 18, Ref. 49). The ISARCO River, like most of the high Alpine rivers, carries (particularly at flood conditions) a great deal of solid material in the form of gravel, sand, mud, etc., which amounts to unusual proportions of 0.03 m^3 per 1 m^3 of flow. In the case of the 90 m^3/sec power plant discharge, this amounts to 5000-15,000 m^3 of solid material per day. This may explain the special precautions applied in the construction and operation of the sedimentation plant. The sedimentation basins are 11.0 m wide and 25 m long each, handling 18 m^3/sec. The suspended material may be flushed back into the ISARCO River. The flow velocity in the basins is 0.45 m/sec. Each basin has three entrance openings at the river side equipped with protective rakes and sluice gates. The cleared water may be directed through a bypass directly into the main conduit. It can be also transferred into the storage reservoir. There are three different methods of operation of this plant, according to flow conditions of the ISARCO and according to season. (See Figs. 1-5, pp 129-133 of Reference 50).

3. Reservoir. The storage reservoir serves for daily storage with a capacity of 0.29 million m^3. Settling of the stored water also helps to clear it from silt. It can be emptied by a bottom outlet on each side of the reservoir, the outflow emptying into the scouring canal of the sedimentation plant (see Figs. 20 & 23, p 971 of Ref. 49). Twenty upper openings each 2.00 x 1.30 m and twenty lower openings each 2.00 x 1.25 m equipped with gates, provide for the release of stored water into the power plant conduit (see Fig. 21, p 972 of Ref. 49).

(d) Power Plant Conduit.

1. This consists of a free surface intake gallery 14,843 m long (see Figs. 3, 26, 27, p 961 of Ref. 49) designed to carry 90 m^3/sec. The hydraulic characteristics have been determined on the basis of a minimum friction coefficient of 0.06 in Bazin's Formula. Based on this, the gradient is 0.075 percent and the mean velocity 3.10 m/sec. (For cross-section details, see Figs. 26, 27 of Ref. 49). The area of the conduit cross-section is 31.40 m^2, the area of flow is 29.0 m^2.

2. At the end of the intake gallery is a patented hydraulic device, a sort of flow-controlling "ventola"

gate which provides for the transfer of flow from the intake gallery into the surge gallery. The surge gallery is 1229 m long and its cross-section has an area of 70.0 m^2 and wetted area of 66.0 m^2 (see Figs. 28, 29, p 975 of Ref. 49). The "ventola" also regulates excessive flow in the intake gallery by shutting the automatic valve. As a result, the gallery may become completely filled for as far as 6,000 m above the gate, creating a 4.5 m pressure. At the same time, the accumulated water there amounts to 0.15 m^3. The storage capacity of surge chamber and surge gallery when filled is 0.06 million m^3. Together with the 0.29 million m^3 storage in the PONTE ALL'ISARCO Reservoir, the total storage capacity is over 0.50 million m^3. In the surge chamber, the accumulated water may rise to an elevation of 442.20 m above msl.

(e) GARDENA-BOLZANO Power Plant. Five penstock pipes of 2.80 m diameter and one pipe of 2.0 m diameter direct the flow to the power plant. The five larger pipes serve five Francis turbines each having 45,000 HP capacity; the smaller penstock leads to three Pelton wheels each having 15,000 HP capacity and two Pelton wheels, each having 500 HP capacity. The smaller group of five Pelton wheels supplys the power for the main line of the BOLZANO-BRENNER railroad. Reference should be made to the article listed as Reference 49 for detailed description of the various special devices of this development.

(6) TALVERA River Development.
(Basis: Reference 4)

The TALVERA River which joins the ISARCO River at the City of BOLZANO is a very steep Alpine stream carrying a great amount of detrited material which, at high stages, moves into the lower reaches of the ISARCO River. This results in very adverse effect upon its flow. To avoid this undesirable condition, the Italian government has been planning since 1937 to construct a protective dam on the TALVERA River near the village of VANGA at the confluence of the GENESIO and TALVERA Rivers 3 km from BOLZANO. The purpose of this is to retain solid material and at the same time to act as a flood protection structure. The storage lake above the dam was to have 20 million m^3 storage capacity in its area of 30 hectares. The present status of this project is not known.

e. NOCE River.

(1) CARESER Development.
(Basis: References 40, 56 & 57)

(a) CARESER Dam. (Serial No. R-26)

This dam is located on the CARESER Stream, the outflow of the CARESER Lake. The dam is of gravity type 60 m high. Its crest elevation is 2,601.00 m above msl; crest length is 444 m. The dam is constructed of concrete with expansion joints every 18 m. The utilized capacity of the storage lake is 16 million m^3. The dam was built in the period from 1928-1932 according to Reference 40; however, Reference 56 gives 1930-1934 as the period of construction.

(b) MALGAMARE Power Plant. The power conduit from CARESER Dam to the power plant is imbedded in the rock. The power plant also utilizes flow of the stream leading from the NOCE BIANCO Glacier. Because of the muddy condition of the water, the power plant is equipped with a "Du Four" sedimentation plant in addition to a large sedimentation basin. The power capacity of the MALGAMARE power plant is 12,000 KW; its annual output is 56.5 million KWH.

(2) COGOLO Development.

(a) General. This development has been in operation since 1929 and has been progressively enlarged in later years.

(b) PIAN PALU Dam. (Serial No. R-27) This dam has been under construction since 1951. The plans provide for a rock-fill masonry dam with 16.7 million m^3 storage capacity and 55 hectares lake area. The maximum stage elevation is to be 1,745 m above msl., thus effecting a 55 m increase in stage. The crest of the dam is to be 175 m long and 52 m high above the floor of the valley. The rock-fill dam is to be covered on the headwater side by 2 to 6 m thick concrete masonry and 0.40 m thick concrete plates. The dam is being constructed in progressive steps at elevations 1763.5 m, 1775.0 m, 1785.0 m, and ultimately at 1800.0 m above msl. In order to gain additional storage, the alluvial fill at the bottom of the reservoir was removed by hydraulic dredging.

(c) COGOLO POWER PLANT. The hydraulic head utilized at this plant is 599.2 m. The ultimate power capacity of the completed development at COGOLO will amount to 94,000 KW with an annual output of 116.5 million KWH.

(3) S. GIUSTINA-TAIO Development.

(a) S. GIUSTINA Dam. (Serial No. R-28) (Basis: References 56, 57, & 58)

1. General. This dam was completed by

the Societa Edison in 1951. Reference is made to Plate 8d of this report for sketches of the dam and to Table 4 of the report for summary of dam data. Certain characteristics of the project appear in the following tabulation:

Drainage area	1050 km^2
Gross storage	182.2 km^3 (172 re Ref. 57 & 180 re Ref. 58)
Maximum pool elevation	530.2 m above msl
Minimum pool elevation	445.0 m above msl
Area of pool	350 hectares
Flow utilized for power	66 m^3/sec

2. Dam Structure. S. GIUSTINA is an arch dam which blocks the narrow precipitous gorge through which the NOCE River forces its course. The dam arch is 16.5 m thick at the base, 3.5 m at the crest. The total height of the dam is 152 m. The crest elevation is 532.5 m above msl. The dam was built in blocks, each 30 m long, separated by joints 1.9 m wide. The joints were plugged after sufficient time had elapsed for the concrete to mature. The bottom and the sides of the gorge are of calcareous dolomite which, prior to the construction of the dam, were solidified by extensive injections (see Fig. 25 of Ref. 57 or Fig. I of Plate 8d of this report).

3. Relief Structures. On account of great flood dangers, several relief structures are developed (see Fig. III of Plate 8d of this report). These relief structures are as follows:

a. Diversion tunnel on the right bank, plugged on completion of the dam.

b. Intake for the power tunnel on the left bank, also including an intake for the scour tunnel for emptying the bottom of the reservoir.

c. A second scour tunnel on the left bank for discharging the middle levels of the reservoir.

d. A spillway tunnel on the right bank with a spillway at the top reservoir level.

The emptying of the reservoir is provided at three levels. The spillway consists of two sluice gates each 9 x 4.5 m located at

the entrance of a steeply sloping tunnel which leads into the downstream end of the diversion tunnel. The intermediate scour tunnel has two gates in series, a guard gate 2.8 x 4.3 m and a control gate 2.8 m x 4.2 m, operated by an oil servo-motor; the outlet tunnel downstream of the gates is 172 m long and the maximum head on the gates is 58 m. The bottom scour tunnel also has two gates in series measuring 2.3 m x 3.7 m and 2.3 m x 3.6 m, respectively, operated by an oil pressure servo-motor. (A sketch of this tunnel appears in Fig. IV of Plate 8d of this report). In this case, the gates operate under a head of 97 m; the tunnel is 145 m long. The various control gates in the left bank tunnel intakes are controlled from underground control rooms, the access shaft to which may be seen in Fig. III on Plate 8d of this report. The total capacity of the three discharge openings is 1000 m^3/sec at normal maximum water surface of 530.0 m. The outlets can handle 1500 m^3/sec if the water level is permitted to rise to 532.5 m, the elevation of the crest of the dam. The power tunnel is controlled by an automatic gate 2.7 m x 4 m in size.

(b) TAIO Power Plant.

1. The power conduit from S. GIUSTINA Dam is of circular cross-section 5.2 m in diameter, 2052 m long, and is designed for a maximum flow of 66 m^3/sec. The maximum head is 90 m at the intake and 107 m near the penstock. The steel penstock has a diameter varying between 3.7 m and 3.5 m, and is supported freely in a shaft. Close to the head of the penstock, there is a vertical surge shaft 102 m high with a spiral expansion chamber.

2. The tailrace tunnel of the TAIO power plant is 1270 m long and usually operates under a low head. The expansion chamber has been excavated below the sluice gate in the power station tailrace. The upper end of the chamber forms an emergency outlet for the penstock shaft.

3. Access to the power station is by 2 km steeply sloping road leading from the TRENTO-MALE HIGHWAY to the portal of a 325 m horizontal access tunnel.

4. The power generating equipment of the plant consists of three vertical axis Francis turbo-alternator sets, each of 41,000 KVA capacity, and four transformers each of 70 KVA capacity. Transformers with voltage ratings of 10, 150, and 240 KV complete the equipment of the power plant. The entire power plant is underground.

(4) MEZZOCORONA Development.
(Basis: Reference 60)

(a) General. The development was constructed in the period between 1926-1929.

(b) MOLLARO Reservoir. (Serial No. R-29)

The tailrace of TAIO power plant empties into the reservoir constructed near MOLLARO, which serves as a weekly storage reservoir for this development. Its storage capacity is 850,000 m^3. The reservoir is formed by a dam at which the maximum storage elevation reaches 347.0 m, minimum elevation 339.0 m above msl.

(c) MOLLARO-MEZZOCORONA Conduit and Power Plant.

1. The outstanding feature of this development is the power conduit (see Figs. 1-2 of Ref. 60). The conduit is 9085 m long. Of this length, 7 km is of polycentric cross-section and 2 km of circular cross-section with an area of 20 m^2. The conduit is of reinforced concrete, the thickness of the shell varying from 20 to 70 cm, reinforced by concrete rings 10 and 20 cm thick.

2. The conduit crosses several streams and tributaries of the NOCE River. The most important of these crossings are of the PONGAIOLA River and RINASICO River, which are crossed by means of bridges. (The profile and geological conditions are shown on Fig. 5, p 326 of Ref. 60). The mean gradient of the conduit is 0.02 percent; the total drop is from elevation 333.03 m to 317.80 m above msl. The conduit ends in a surge chamber constructed in such a way as to permit the accumulation of 3400 cm and 2400 cm of flow in two chambers. In the event that the NOCE River flow would reach the catastrophic stage of 361.00 m (14 m above the maximum), the surge chamber could release the excess flow, thus bypassing the penstock (see Fig. 15 of Ref. 60). At normal flow, the velocity inside the conduit is 3 m/sec, corresponding to a discharge of 60 m^3/sec. It may reach up to 80 m^3/sec discharge at 4 m/sec velocity under catastrophic conditions.

3. Two penstock pipes each 2.60 m in diameter carry the flow toward the turbines. The power capacity of the plant is 50,000 KW.

(5) ROCHETTA Dam. (Serial No. R-30)
(Basis: Reference 17)

(a) General. The ROCHETTA Dam was con-

structed in 1937 for the purpose of retaining the alluvial sediment and solid material moving along the 15 km long course of the NOCE River between MOLLARO and ROCHETTA. This movement of solid material was particularly noticeable since the construction of the MOLLARO Reservoir (Serial No. R-29). The ROCHETTA Dam is located at the junction of the RINASICO , PONGAIOLO, LOVERNATICO, SPOREGGIO, and other small streams which also carry a great volume of detrital material.

(b) Dam Structure. The storage capacity of the reservoir is 3.0 million m^3. The dam rises 40 m above the floor of the valley. The dam, a gravity arch of reinforced concrete, is 35 m long at the crest, 1.80 m thick at the middle, and 4.50 m thick at the base.

(c) Outlet. The relief outlet consists of a vertical shaft discharging the flow into a conduit built in the rock and bypassing the dam. Its capacity is 350 m^3/sec. The spillway, located on the right bank, is 17 m long and capable of carrying up to 1000 m^3/sec of catastrophic flood water with a 4.0 m thick nappe. The bottom outlet of the reservoir is located on the left bank 5 m below the crest of the dam.

f. AVISIO River. (Basis: Reference 55)

(1) FEDAIA WEST and FEDAIA EAST Dams. (Serial Nos. R-31 & R-32)

Both dams have been under construction since 1950. The FEDAIA WEST Dam, a gravity arch structure, is located west of the FEDAIA Lake close to MARMOLATA Glacier. It dams the AVISIO River 40 m high on the side of the FASSA Valley. FEDAIA EAST Dam, an earth structure, closes the east end of the storage lake. The storage of this reservoir is redirected towards the CORDEVOLO Valley to be utilized in the CENCENIGHE power plant. The hydraulic characteristics of these dams are as follows:

Storage capacity	16 million m^3
Storage area	70 hectares
Maximum storage elevation	2,053 m above msl
Minimum storage elevation	2,013 m above msl
Height of the west dam	50 m
Height of the east dam	20 m

(2) FORTEBUSSO Dam. (Serial No. R-32) (Basis: Reference 61)

This dam has been under construction since 1950 on the TRAVIGNOLO River at FORTEBUSSO. It is a gravity arch dam. Following are the data of the dam:

Storage capacity	27 million m^3
Storage lake area	63 hectares
Maximum stage elevation	1460.00 m above msl
Minimum stage elevation	1380.00 m above msl
Height of the dam	110 m
Length of dam at crest	330 m

(3) POZZOLAGO Development. No data were presently available concerning this development.

g. LOWER ADIGE below VERONA. (Basis: Reference 4)

(1) General. The orohydrographic characteristics of the ADIGE drainage area indicate the flooding potentialities of that portion of the VENETIAN PLAINS, which extends along the ADIGE between VERONA and the ADRIATIC SEA.

(2) Hydrologic Conditions. The main contribution to the ADIGE flow comes from the numerous tributaries of the High Alpine region of "ALTO ADIGE" Province, which extends north from ALA to BRENNER PASS. According to Reference 4, 90 percent of the drainage area of the ADIGE River is located in this mountainous part of Italy. However, the portion of the ADIGE which flows south of ALA requires permanent protection against sudden outburst of floodwaters. Approximately 316 km (according to information dated 1937) of dikes are required between ALA (at the pre-1918 Italo-Austrian international boundary) and the mouth of the ADIGE at the ADRIATIC SEA, in order to protect 77,000 hectares of land (770 km^2) on the left banks and 2,540 km^2 on the right side against floods.

(3) Maximum Floods. Since historical times (1512), the river gage located at the historical city of TRENTO was used as the indicator of threatening flood conditions in the VENETIAN PLAINS originating on the ADIGE River. (See Fig. 50, p 126, of Ref. 4 for hydrologic data at TRENTO for the period 1865-1934). The 1882 flood seems to be the highest ever achieved in the recorded period. The 1926 flood, however, was the most studied. (All prewar information). At the crest of the 1882 flood, the TRENTO gage showed 6.11 m above the gage zero which corresponds to an estimated discharge of 2020 m^3/sec (other sources estimate 2,400 m^3/sec). The 1926 flood, registered at TRENTO, reached a stage of 5.40 m above gage zero, corresponding to 1600 m^3/sec discharge, 4.45 m/sec maximum velocity at the front of the flood wave, and 3.77 m/sec mean surface velocity.

(4) Flood of 1882. The following description indicates the progress of the flood in 1882:

A-09 f (4)

(a) On September 17th, when first warnings were given out on the danger of the flood, based on readings at the TRENTO gaging station, the 250 km of flood protection levees between VERONA and the sea had been reinforced and raised. Despite this, breaches occurred at S. MICHELE, S. MARTINO, and at SORIO, causing a large territory around VERONA to be flooded (see Table VIII, p 106, of Ref. 4). Plate 10 of this report shows the extent of the area flooded and the location of natural and artificial levee breaks.

(b) At midnight 17-18 September, a 60 m break occurred at CA MOROSINI, also a 670 m break at MASI.

(c) At LEGNAGO, at 3:00 AM on the 18th of September, a 300 m long break of the right bank dike, started an enormous flow into the valley of VERONA (VALLE GRANDI VERONESI). It is to be noted that the ADIGE bed at this location is 1.50 m higher than the floor of the adjacent depression. The furious currents thus generated, disrupted the VERONA-ROVIGO railroad line and descended very swiftly in the depression along the right bank of the ADIGE and left bank of CANAL BIANCO. This flow engulfed the upper reach of the TARTAR River, and continued along CANAL BIANCO to FOSSA POLESSELLA.

(d) Thirteen days after the start of the flood, on October 1st, it was found necessary to release the accumulated flood water (which, in some places, reached up to 8 m depth) toward the sea. By means of four deliberate breaches of the FOSSA POLESSELLA dikes, the water descended 5 m high above the terrain into the territory limited by the PO River and CANAL BIANCO, proceeding further into the sea.

(e) The flooded territory extended over 170 km^2 on the left and 1,090 km^2 on the right, totaling 1,260 km^2, according to GIORNALE DEL GENIO CIVILE OF 1897.

EXHIBIT B

GAZETTEER

VENETIAN-FRIULI PLAINS
OF NORTHEAST ITALY

EXHIBIT B

GAZETTEER

VENETIAN-FRIULI PLAINS
OF NORTHEAST ITALY

PLACE	MAP SHEET NO.*	U.T.M. GRID REFERENCE
ADIGE RIVER, MOUTH	65	9004
AGORDO	23	7130
AIBA DAM	26	9506
ALA (BUSSOLENGO) DAM	36	5468
ALBA DAM	14	6243
ALBEREDO D'ADIGE	63	7721
ALPONE RIVER, MOUTH	49	7722
ALTIVOLE	38	3071
AMPEZZO CARNICO	13	3042
ANGUILLARA VENETA	64	2602
ANSIEI RIVER, MOUTH	13	0453
ARCADE	38	8474
ARZINO RIVER, MOUTH	25	4217
ASTICO RIVER, MOUTH	50	0456
AUSSA RIVER, MOUTH	40	6368
AVIANO RIVER, MOUTH	35	5166
AVIO	35	5166
AVISIO RIVER, MOUTH	21	6110
BACCHIGLIONE RIVER, MOUTH	65	8307
BADIA POLESINE	64	9795
BAGNARIA ARSA	40	6783
BASSANELLO	50	2430
BASSANO	37	1372
BELLUNO	23	8211
BOARA PISANI	64	1998
BOITE RIVER, MOUTH	12	9641
BOLZANO	10	8152
BREDA DI PIAVE	38	9266
BRENNER PASS	1	9008
BRENTA RIVER, MOUTH	65	8807
BRENTONE RIVER, MOUTH	65	8407
BRESSANONE	4A	0377
BRUSEGANA	50	2131
BUSSOLENGO	48	4437
BUT RIVER, MOUTH	14	4640

*AMS Map Series M691 (GSGS Series 4164), 1:100,000

CALDARO LAKE	10	7438
CALDONAZZO LAKE	21	7300
CA MOROSINI	64	0698
CAMPOCROCE	12	7769
CAMPO, DI SOTTO	12	7956
CAMPO S. MARTINO	50	1947
CANALE D'ISONZO	26	9404
CANEVA	38	0294
CA PASQUA (CA PASCA)	65	8307
CAPRILE DAM	12	6947
CARBONERA	38	8862
CARDANO	10	8351
CARESER DAM	9	3042
CARESER RIVER, MOUTH	9	2941
CARSO (VIPACCO) RIVER, MOUTH	40A	8784
CASALE SACILE	40	5180
CASARSA	39	3391
CASELLO	39	3791
CASTAGNARO	63	8999
CASTELBELLO	9	4665
CASTELFRANCO	37	2862
CASTELLETTO	38	9494
CASTELVIERO	38	8280
CAVANELLA D'ADIGE	65	8393
CAVARZERE	65	7002
CAVAZZO LAKE	25	5132
CENCENIGHE	12	2938
CERAINO	48	4248
CERVIGNANO DEL FRIULI	40	7075
CHIEVO	48	5235
CHIOGGIA	65	8611
CIMA D'ASTA	22	9814
CIMALDOLMO	38	9574
CIMAGOGNO	12	0453
CISMON RIVER, MOUTH	37	1190
CITTADELLA	50	1759
CODEVIGO	65	7217
COGOLO	9	3034
COMELICO DAM	13	0756
CONCHE	65	7813
CORDEVOLE RIVER, MOUTH	23	7406
CORITENZA RIVER, MOUTH	26	1313
CORNO RIVER, MOUTH	40	6268
CORTE	65	7121
CORTELLAZZO	52	2245
CORTINA D'AMPEZZO	12	8158
CROCETTA DEL MONTELLO	38	6979
CROSIS DAM	25	6322

DEBBA	50	0141
DEGANO RIVER, MOUTH	13	3941
DERMULO	10	5833
DOBBIACO (TOBLACH)	4B	8878
DOBLARI (DOBLAR)	26	9908
EGA RIVER, MOUTH	10	8352
ESTE	64	0811
FADALTO	23	9406
FALZE	38	7982
FEDAIA EAST DAM	11	2148
FEDAIA WEST DAM	11	2148
FELLA RIVER, MOUTH	14	5536
FELTRE	22	2600
FENER	37	2887
FERSINA RIVER, MOUTH	21	6301
FIASCHETTI	39	0495
FONTANIVA	50	1356
FORNI DI SOPRA	13	1444
FORTEBUSSO DAM	22	0731
FORTEZZA DAM	4A	0084
FOSSA POLESELLA	76	1882
FOSSONE	65	8702
FRAFOREANO	40	4377
FUNES DAM	11	9870
FUNES RIVER, MOUTH	11	9870
GALLINA RIVER, MOUTH	23	9122
GARDA LAKE (LAGO DI GARDA)	35	—
GARDENA RIVER, MOUTH	11	9363
GENESIO RIVER, MOUTH	10	8155
GIOVARETTO DAM	9	3251
GLORENZA	3	1770
GORICE (GORIZIA)	40A	9389
GRADISCA	40A	8483
GRIGNO RIVER, MOUTH	22	0499
GRISOLARA	52	1849
IDRIA RIVER, MOUTH	26	0211
IGNA RIVER, MOUTH	50	9655
IMPIANTO MARLENGO	10	8152
IMPIANTO TEL	10	6568
INVILLINO	13	4041
ISARCO (EISACK) RIVER, MOUTH	10	7647
ISONZO RIVER, MOUTH	40A	8764
ISTRANA	38	7462

LAGO DELLE PIAZZE DAM	21	7513
LAGO DI ALIEGHE DAM	12	7042
LAGO DI MEZZO	3	1782
LAGO DI RESIA	3	1686
LAGO MORTO DAM	23	9203
LAGO RESTELLO DAM	23	9101
LAGO S. CROCE DAM	23	9312
LANDRO	12	8868
LATISANA	40	4470
LEGNAGO	63	8107
LENDINARA	64	0595
LEOGRA RIVER, MOUTH	36	8961
LEVICO	21	7898
LEVICO (LAKE)	21	7698
LIMENA	50	2240
LIVENZA	39	0789
LIVENZA RIVER, MOUTH	52	3350
LONGARONE	23	9227
LORENZAGA	13	0650
LOVERNATICO RIVER, MOUTH	21	5823
LUMIEI DAM	13	2546
LUMIEI RIVER, MOUTH	13	3440
LUSIA	64	0997
MAE RIVER, MOUTH	23	9226
MALGAMARE	9	2841
MANGART	14A	nr. TRICORNO
MANTOVA	62	4102
MARLENGO	10	6369
MASERADA	38	9170
MASER ASOLO	37	2676
MASI	64	9598
MASO RIVER, MOUTH	22	0294
MESCHIO (MESCHIA) RIVER, MOUTH	39	9390
MELMA	51	8959
MERANO	10	6568
MESTRE	51	8542
MEZZOCORONA	21	6320
MOLLARO DAM	21	5828
MONFALCONE	40A	8774
MONTEBELLUNA	38	7073
MONTEGALDELLA	50	0935
MONTELLO	38	7673
MONTE PERALBA	13	2667
MORGANO	51	7459
MORI DAM	36	5580
MOTTA DI LIVENZA	39	1572
MUSILE DI PIAVA	52	1055
MUSSONE DEI SASSI RIVER, MOUTH	40	2636

NATISONE RIVER, MOUTH	40	7389
NERVESA DELLA BATTAGLIA	38	8378
NOCE RIVER, MOUTH	21	6012
NOVE	23	9203
OROLO RIVER, MOUTH	50	9649
PADOVA	50	2636
PAESE	38	7862
PAPARIANO	40	7874
PASSIRIO RIVER, MOUTH	10	6370
PASSO CANUSSIO	40	4278
PEDEROBBA	38	2984
PELOS	13	0652
PERAROLO	12	9641
PERGINE	21	7304
PESCATINA	48	4538
PIAN DEI MORTI	3	1988
PIAN PALU DAM	9	2433
PIAVE RIVER, MOUTH	52	2244
PIAZZOLA SUL BRENTA	50	1747
PIERIS	40	7874
PIEVE DI CADORE DAM	12	9944
PINE RIVER, MOUTH	21	6905
PIOVE DI SACCO	65	6720
PIOVERNO	14	5633
PLAN DEL SAC	13	2944
PLAVA (PLAVE)	26	nr. AIBA
PLEZZO	14A	8933
PLIMA DAM	9	3656
PLIMA RIVER, MOUTH	9	4064
PODESTAGNO	12	7965
POMAGAGNON	12	8163
PONGAIOLA RIVER, MOUTH	21	5926
PONTE ADIGE	10	7650
PONTE ALL'ISARCO DAM	11	9363
PONTE DELLA SERRA DAM	22	1301
PONTE DI BRENTA	50	3034
PONTE DI FENER	37	2887
PONTE DI PIAVE	39	0465
PONTE DI PINZANO	24	4216
PONTE DI PRIULA	38	8677
PONTE DI SALCANO	40A	9592
PONTE MEDUNA	39	2190
PONTE ROVINA	20	4031
PONTE VIGODARZERE	50	2637
PONZANO VENETO	38	8365
PORDENONE	39	1893
PORTOGRUARO	39	3272
PORTO NOGARO	40	6175

POVEGLIANO	38	8271
POZZOLAGO	21	7315
PRA DA STUA DAM	35	4870
PRECENICCO	40	5072
PRIMOLANO	37	1094
PRIULA	38	8677
PUNI RIVER, MOUTH	9	2266
PUSTERIA (RIO DI PUSTERIA) DAM	4A	0386
QUERO	37	2789
QUINTO TREVISO	51	7958
RESIA	3	1588
RIENZA RIVER, MOUTH	4A	0377
RIESE	37	2768
RINASICO RIVER	21	5924
RIVA	35	4383
RIVOLI	48	4148
ROCHETTA DAM	21	5922
RONCHIS	40	4474
ROVERCHIARA	63	7615
ROVERETO	36	5884
ROVIGO	64	2094
RUGE DE GALLO	38	nr. PEDEROBBA
SAGRADO	40A	8482
SALCANO	40A	9592
SALDURA RIVER, MOUTH	9	2167
S. ANASTASIO	39	1965
S. ANDREA DI BARBARANA	39	0264
S. BIAGIO DI CALLALTA	38	9562
S. CASSIANO	39	0883
S. CATERINA DAM	13	0557
S. DONA DI PIAVE	52	0856
S. FLORIANO	23	9101
S. GIOVANNI LUPATOTO	49	6027
S. GIUSTINA DAM	10	5834
S. LUCIA	26	0213
S. MARCO	50	1333
S. MARTINO	49	6332
S. MARTINO DI CASTROZZA	22	1627
S. MICHELE	49	6033
S. UBERTO	12	7865
S. VALENTINO DAM	3	1681
SARCA RIVER, MOUTH	35	4481
SARSON	37	1174
SEGUSINO	37	2889
SENALES RIVER, MOUTH	10	5168
SERRAVILLE	36	5675

SILE RIVER, MOUTH	52	1138
SORIO	49	6029
SOTTOSELLA (PODSELLA) DAM	26	0110
SOVERZENE DAM	23	9120
SPOREGGIO RIVER, MOUTH	21	5822
SPRESIANO	38	8673
STANGA (ALBERGO LA STANGA)	23	7822
STELLA RIVER, MOUTH	40	5265
STRA	51	6633
STRIGNO	22	9704
TAGLIAMENTO RIVER, MOUTH	53	5256
TAIO	21	5931
TALVERA RIVER, MOUTH	10	8051
TARVISIO	14A	9151
TASSO RIVER, MOUTH	48	4143
TESINA RIVER, MOUTH	50	0341
TIMONCHIO RIVER, MOUTH	50	9755
TOIMINO	26	0216
TORRE RIVER, MOUTH	40	7775
TRAVIGNOLA RIVER, MOUTH	22	9931
TRENTO	21	6304
TREVIGNANO	38	7169
TREVISO	51	8561
TRIESTE	53A	0558
TRICORNO	14A	1138
UDINE	25	6303
VAJON RIVER, MOUTH	23	9227
VAJONT DAM	23	nr. LONGARONE
VAL GALLINA DAM	23	9321
VALLE DAM	12	9343
VANGA	10	8055
VARMO	40	4483
VEDALGO	38	6763
VENAS	12	9243
VENETO	37	2661
VENEZIA (VENICE)	51	9035
VENZONE	25	5733
VERNAGO DAM	3	4077
VERONA	49	5634
VICENZA	50	9946
VILLAVERLA	50	9458
VILLORBA	38	8469
VIPACCO (CARSO) RIVER, MOUTH	40A	8784
VODO	12	8845
VOLTA BRUSEGANA	50	2230